June 2015

Tacoma Link Expansion

Environmental Evaluation

NOISE AND VIBRATION TECHNICAL REPORT

SOUNDTRANSIT
Central Puget Sound
Regional Transit Authority

U.S. Department of Transportation
Federal Transit Administration

Tacoma Link Expansion

Noise and Vibration Technical Report

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Sound Transit

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June 2015

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Acronyms and Abbreviations

ANSI	American National Standards Institute
dB	decibels
dBA	A-weighted decibels
EDNA	Environmental Designation for Noise Abatement
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
FTA	Federal Transit Administration
HUD	Department of Housing and Urban Development
HVAC	heating, ventilation, and air conditioning
Hz	hertz
I-5	Interstate 5
in./sec.	inch(es) per second
Ldn	day-night equivalent sound level
Leq	equivalent sound level
Lmax	maximum overall noise level
Lv	vibration velocity level
MLK Jr. Way	Martin Luther King, Jr. Way
mph	miles per hour
N/A	not applicable
NIST	National Institute of Standards and Technology
OMF	operations and maintenance facility
PPV	peak particle velocity
RMS	root mean square
Sound Transit	Central Puget Sound Regional Transit Authority
TLE	Tacoma Link Expansion
VC	vibration criteria
VdB	vibration decibels
WAC	Washington Administrative Code

1.0 Introduction and Summary

This technical report presents a noise and vibration impact study for the Tacoma Link Expansion (TLE) being proposed by Sound Transit. The objective of the study is to assess the potential noise and vibration impacts of the proposed transit project.

Section 1.0 of the report describes the background and results of this noise and vibration assessment. Section 2.0 discusses environmental noise and vibration basics, and Section 3.0 describes the existing conditions and noise and vibration measurement results. The criteria and methods used to assess noise and vibration impacts are presented in Sections 4.0 and 5.0, respectively. Sections 6.0 and 7.0 provide the noise and vibration impact assessment results, and Section 8.0 outlines potential mitigation measures. Section 9.0 lists the references used in writing this report. Appendix A includes detailed photos of the noise and vibration monitoring locations, Appendix B provides detailed noise impact assessment data, and Appendix C presents the detailed vibration impact assessment.

The noise analysis was performed for 166 individual properties representing approximately 732 residences, medical buildings, institutional uses, commercial buildings, and undeveloped properties along the project corridor. No noise impacts were identified along the corridor. Because of onsite tests and measurements and advanced track design, all vibration levels are predicted to be below the Federal Transit Administration (FTA) criteria with the proposed track installation procedures. As part of final design, additional noise and vibration testing/analysis would be conducted to re-evaluate the project for potential impacts and mitigation measures.

2.0 Environmental Noise and Vibration Basics

This section provides an overview of environmental noise and vibration basics that were followed when conducting this assessment.

2.1 Noise Fundamentals and Descriptors

What humans perceive as sound is a series of continuous air pressure fluctuations superimposed on the atmospheric pressure that surrounds us. The amplitude of fluctuation is related to the energy carried in a sound wave; the greater the amplitude, the greater the energy, and the louder the sound. The full range of sound pressures encountered in the world is so great that it is more convenient to compress the range by using a logarithmic scale, resulting in the fundamental descriptor used in acoustics—the sound pressure level, which is measured in decibels (dB). When sounds are unpleasant, unwanted, or disturbingly loud, we tend to classify them as noise.

Another aspect of sound is the quality described as its pitch. Pitch of a sound is established by the frequency, which is a measure of how rapidly a sound wave fluctuates. The unit of measurement is cycles per second, called hertz (Hz). When a sound is analyzed, its energy content at individual frequencies is displayed over the frequency range of interest, usually the range of human audibility from 20 Hz to 20,000 Hz. This display is called a frequency spectrum.

Sound is measured using a sound-level meter with a microphone designed to respond accurately to all audible frequencies; however, the human hearing system does not respond equally to all frequencies. Low-frequency sounds below about 400 Hz are progressively and severely attenuated, as are high frequencies above 10,000 Hz. To approximate the way humans interpret sound, a filter circuit with frequency characteristics similar to the human hearing mechanism is built into sound-level meters. Measurements with this filter enacted are called A-weighted sound levels, expressed in A-weighted decibels (dBA). Community noise is usually characterized in terms of the A-weighted sound level. Exhibit 2-1 illustrates the A-weighted levels of common sounds.

The range of human hearing extends from about 0 dBA for young healthy ears (that have not been exposed to loud noise sources) to about 140 dBA. When sounds exceed 110 dBA, there is a potential for hearing damage, even with relatively short exposures. In quiet suburban areas far from major freeways, the noise levels during the late night hours would drop to about 30 dBA. Outdoor noise levels lower than this only occur in isolated areas where there is a minimum amount of natural noises, such as leaves blowing in the wind, crickets, or flowing water.

Another characteristic of environmental noise is that it is constantly changing. The noise level increase when a train passes is an example of a short-term change. The lower average noise levels occur during nighttime hours, when human activities are at a minimum, and higher noise levels during daytime hours are caused by daily patterns of noise-level fluctuation. The instantaneous A-weighted sound

level is insufficient to describe the overall acoustic "environment." Thus, it is common practice to condense the fluctuating noise levels into a single number, called the "equivalent" sound level (Leq). Leq can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the day-night equivalent sound level (Ldn, also sometimes abbreviated DNL), which is defined as the 24-hour Leq but with a 10-dB penalty added to each nighttime hourly Leq (with "nighttime" defined as the period from 10 p.m. to 7 a.m.). The effect of this penalty is that any event during the nighttime is equivalent to 10 events during the daytime. This strongly weights Ldn toward nighttime noise to reflect most people being more easily annoyed by noise at night, when background noise is lower and most people are resting.

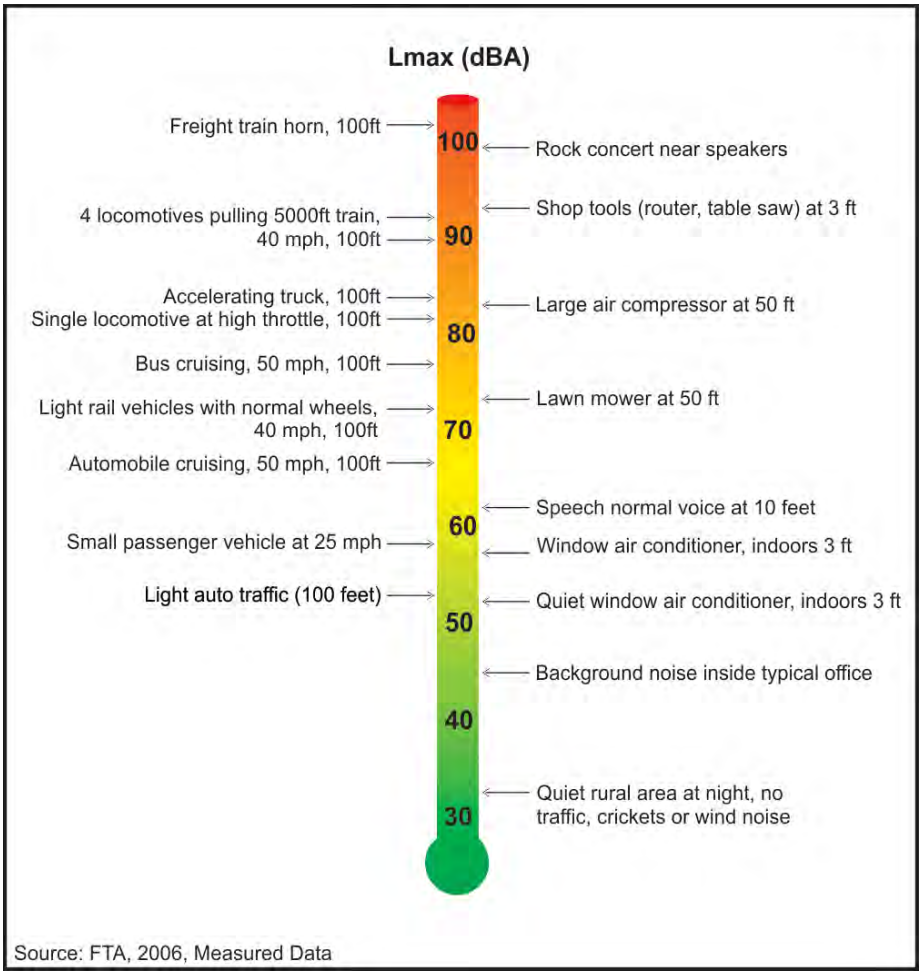
Lmax (dBA)
Freight train horn, 100ft
100
Rock concert near speakers
Shop tools (router, table saw) at 3 ft
4 locomotives pulling 5000ft train, 40 mph, 100ft
90
Accelerating truck, 100ft
Single locomotive at high throttle, 100ft
Large air compressor at 50 ft
80
Bus cruising, 50 mph, 100ft
Lawn mower at 50 ft
Light rail vehicles with normal wheels, 40 mph, 100ft
70
Automobile cruising, 50 mph, 100ft
Speech normal voice at 10 feet
60
Small passenger vehicle at 25 mph
Window air conditioner, indoors 3 ft
Light auto traffic (100 feet)
Quiet window air conditioner, indoors 3 ft
50
Background noise inside typical office
40
Quiet rural area at night, no traffic, crickets or wind noise
30
Source: FTA, 2006, Measured Data

EXHIBIT 2-1
Comparison of Various Noise Levels

Environmental impact assessments for mass transit projects in the United States typically use Ldn to describe the community noise environment at residential locations. Studies of community response to a variety of noises indicate that Ldn is a good measure of the noise environment. Exhibit 2-2 defines typical community noise levels in terms of Ldn. Most urban and suburban neighborhoods are usually in

the range of Ldn 50 dBA to 70 dBA. An Ldn of 70 dBA is a relatively noisy environment that might be found at buildings on a busy surface street, close to a freeway, or near a busy airport, and would usually be considered unacceptable for residential land use without special measures taken to enhance outdoor-indoor sound insulation. Residential neighborhoods that are not near major sound sources are usually in the range of Ldn 55 dBA to 60 dBA. If there is a freeway or moderately busy arterial nearby, or any nighttime noise, Ldn is usually in the range of 60 to 65 dBA.

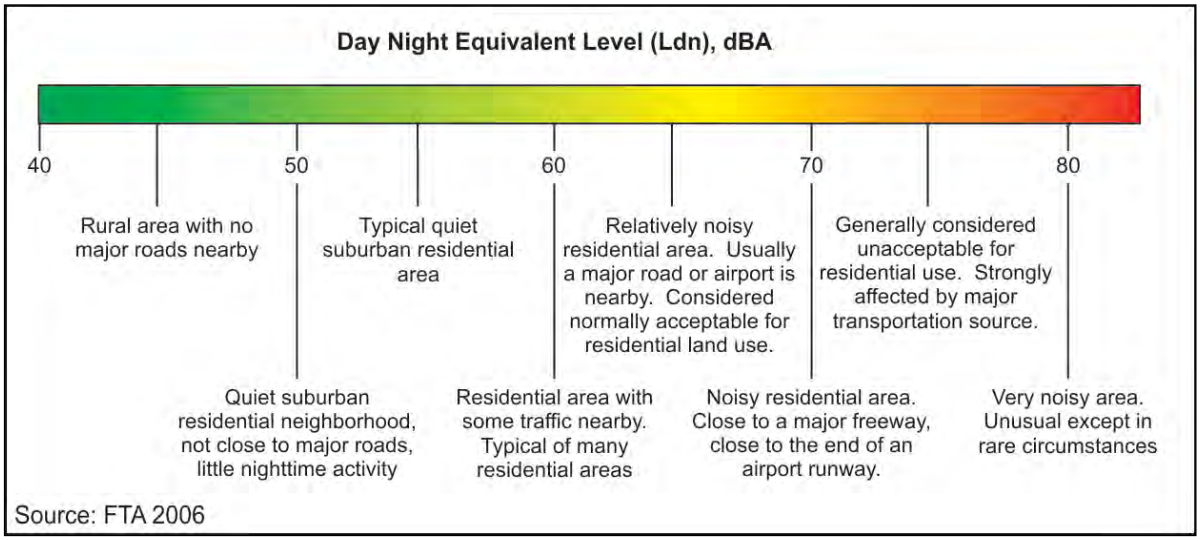
Day Night Equivalent Level (Ldn), dBA
40
50
60
70
80
Rural area with no major roads nearby
Typical quiet suburban residential area
Relatively noisy residential area. Usually a major road or airport is nearby. Considered normally acceptable for residential land use.
Generally considered unacceptable for residential use. Strongly affected by major transportation source.
Quiet suburban residential neighborhood, not close to major roads, little nighttime activity
Residential area with some traffic nearby. Typical of many residential areas
Noisy residential area. Close to a major freeway, close to the end of an airport runway.
Very noisy area. Unusual except in rare circumstances
Source: FTA 2006

EXHIBIT 2-2
Examples of Typical Outdoor Noise Exposure

Ldn is the designated noise metric of choice for many federal agencies, including the Department of Housing and Urban Development (HUD), Federal Aviation Administration (FAA), FTA, and United States Environmental Protection Agency (EPA). Most federal and state agency criteria for noise impacts are based on some measurement of noise energy. For example, the FAA and HUD use Ldn, and the Federal Highway Administration (FHWA) uses peak-hour Leq. The noise impact criteria applicable to residential areas, and included in the FTA guidance manual *Transit Noise and Vibration Impact Assessment* (FTA, 2006), use both Leq and Ldn to characterize community noise.

The City of Tacoma Municipal Code uses a maximum increase over the existing ambient noise level for its noise control ordinance. These criteria are applicable to the noise analysis of ancillary facilities such as maintenance facilities, as well as construction activities. More detailed information on the City of Tacoma Municipal Code is provided in Section 4.2.1.

2.2 Vibration Fundamentals and Descriptors

One potential community impact from the proposed project is vibration that is transmitted from the tracks through the ground to adjacent houses. This is referred to as groundborne vibration. When evaluating human response, groundborne vibration is expressed in terms of decibels using the root mean square (RMS) vibration velocity. RMS is defined as the average of the squared amplitude of the vibration signal. To avoid confusion with sound decibels, the abbreviation VdB is used for vibration

decibels. All vibration decibels in this report use a decibel reference of 1 micro-inch per second (μin/sec.).

The potential adverse impacts of groundborne vibration from Tacoma Link vehicles are as follows:

- Perceptible building vibration: The vibration of the floor or other building surfaces that the occupants feel. Experience shows that the threshold of human perception is around 65 VdB and that vibration that exceeds 75 to 80 VdB is perceived as intrusive and annoying to occupants.
- Rattle: The building vibration can cause rattling of items on shelves and hangings on walls, and various rattle and buzzing noises from windows and doors.
- Reradiated noise: The vibration of room surfaces radiates sound waves that are audible to humans (groundborne noise). Groundborne noise sounds like a low-frequency rumble. Usually, for a system such as the proposed Tacoma Link vehicles, the groundborne noise is masked by the normal airborne noise radiated from the transit vehicle and the rails.
- Damage to building structures: Although it is conceivable that vibration from the Tacoma Link system could damage fragile buildings, the vibration from rail transit systems is one to two orders of magnitude below the most restrictive thresholds for preventing building damage. Therefore, the vibration impact criteria focus on human annoyance, which occurs at much lower amplitudes than does building damage.

Vibration is an oscillatory motion that is described in terms of the displacement, velocity, or acceleration of the motion. The response of humans to vibration is very complex. However, the general consensus is that for the vibration frequencies generated by vehicles such as those that would be used on the Tacoma Link, human response is best approximated by the vibration velocity level. Therefore, this study uses vibration velocity to describe vibration levels generated by the Tacoma Link vehicles.

Exhibit 2-3 shows typical vibration levels from rail and non-rail sources, as well as the human and structure response to such levels.

Although there is relatively little research into human and building response to groundborne vibration, there is substantial experience with vibration from rail systems. In general, the collective experience indicates that:

- It is rare that groundborne vibration from transit systems results in building damage (even minor cosmetic damage). Therefore, the primary consideration is whether or not the vibration is intrusive to building occupants or interferes with interior activities or machinery.
- The threshold for human perception is approximately 65 VdB. Vibration levels in the range of 70 to 75 VdB often are noticeable but acceptable. Beyond 80 VdB, vibration levels are considered unacceptable.
- For human annoyance, there is a relationship between the number of daily events and the degree of annoyance caused by groundborne vibration. The FTA guidance manual includes an 8 VdB higher

impact threshold if there are fewer than 30 events per day, and a 3 VdB higher threshold if there are fewer than 70 events per day.

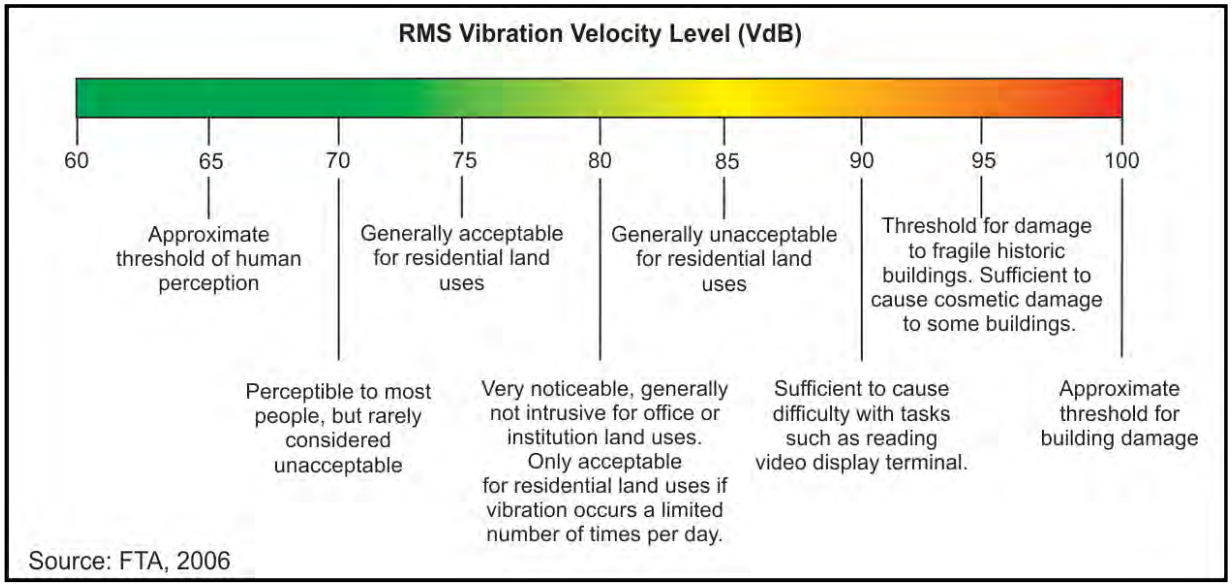
RMS Vibration Velocity Level (VdB)
60
65
70
75
80
85
90
95
100
Approximate threshold of human perception
Generally acceptable for residential land uses
Generally unacceptable for residential land uses
Threshold for damage to fragile historic buildings. Sufficient to cause cosmetic damage to some buildings.
Perceptible to most people, but rarely considered unacceptable
Very noticeable, generally not intrusive for office or institution land uses. Only acceptable for residential land uses if vibration occurs a limited number of times per day.
Sufficient to cause difficulty with tasks such as reading video display terminal.
Approximate threshold for building damage
Source: FTA, 2006

EXHIBIT 2-3
Typical Ground Vibration Levels and Human/Structural Response

Often it is necessary to determine the contribution at different frequencies when evaluating vibration or noise signals. The 1/3-octave band spectrum is the most common procedure used to evaluate frequency components of acoustic signals. The term octave is borrowed from music, where it refers to a span of eight notes. An octave consists of three 1/3 octaves. The 1/3-octave band spectrum of a signal is obtained by passing the signal through a bank of filters. Each filter excludes all components except those that are between the upper and lower range of one 1/3-octave band. The result is a set of vibration levels, one for each of the 1/3 octave bands, which can then be compared to the appropriate regulatory requirements.

3.0 Affected Environment

Sound Transit examined the project corridor to identify noise- and vibration-sensitive locations and select locations where noise and vibration monitoring would be performed. The potential area of affect for the noise study was determined by modeling the worst-case operational noise levels and including all noise-sensitive properties within that area that have a potential for experiencing a noise impact. For the vibration analysis, impacts normally only occur within 50 to 150 feet of the trackway, depending on speed, type of track, and geological factors; therefore, all structures located adjacent to the proposed corridors were evaluated for vibration impact.

The following sections describe the land use along the project corridor, the existing noise-level measurements, vibration testing sites, and the current noise sources in the project corridor. A discussion of the OMF is also included in these sections.

3.1 Land Use

This section provides an overview of the land uses along the proposed corridor. Noise impacts under the FTA guidance manual (2006) are based on the land use type. Complete details on the regulatory categories are provided in Section 4.0, Noise and Vibration Impact Criteria. Exhibit 3-1 shows the land uses in the project vicinity.

3.1.1 Operational Area

The TLE would begin at the Theater District Station on Commerce Street, about half-way between S 9th Street and S Stadium Way. South of that station, there is an apartment complex on the west side of Commerce Street at S 9th Street and twelve condominiums in a building just to the north. Both locations have commercial properties at the ground level. From the station and north to S Stadium Way, there are a series of commercial properties and parking lots on the west side of Commerce Street. The east side of Commerce Street is a mix of parking structures, commercial, retail, warehouse, and office buildings from the station to S Stadium Way, with the exception of the Rescue Mission located at 702 Pacific Avenue.

Land use along the west side of S Stadium Way up to Division Avenue is predominantly residential with some commercial buildings. The residences consist of large apartment complexes and condominium communities that have scenic waterfront views, and the east side of the roadway is undeveloped. There is a YWCA on the corner of S 4th Street with an adjacent office building.

After S Stadium Way, the TLE would travel north along N “E” Street and then southwest along N 1st Street, passing Stadium High School and continuing to Division Avenue. The alignment would also pass near the new Stadium High School annex, which houses the school’s gym and performing arts center. There is one commercial office building along N “E” Street at 15 N Broadway. The remainder of the buildings on both sides of N “E” Street are apartment and condominium complexes.

TACOMA LINK EXPANSION

EXISTING LAND USE

EXHIBIT 3-1

0 0.125 0.25 0.5 Miles

LEGEND

- Existing Stations
- Proposed Stations
- Existing Alignment
- Proposed Alignment
- Existing Operations and Maintenance Facility Site
- Proposed Operations and Maintenance Facility Expansion Site

Existing Land Use

- Residential
- Commercial
- Hospitals/Medical
- Institutional
- Parks
- Civic/Public
- Industrial/Manufacturing

SOUNDTRANSIT
RIDE THE WAVE

The southeast side of N 1st Street is lined with commercial properties. The northwest side of the street includes Stadium High School, commercial uses, and parking lots. Three apartment buildings are located at the intersection of N 1st Street and Division Avenue across from Wright Park.

From N 1st Street, the TLE would continue southwest along Division Avenue to Martin Luther King, Jr. Way (MLK) and would turn south down MLK to its terminus between S 18th and S 19th streets. Land use along the northwest side of Division Avenue consists of a gas station, restaurants, and office buildings. At N "J" Street, two single-family residences have a direct line of site to the proposed alignment and a multi-family residence behind the Center for Spiritual Living. Along the southeast side of Division Avenue is Wright Park (which was determined through noise monitoring as not noise sensitive), the First Church of Christ, Scientist, and the First Congregational Church and School. A medical office building is located on the northeast and southeast corners of the intersection of Division Avenue and N "K" Street.

The MultiCare Tacoma General Hospital campus is located at the north end of MLK and stretches for several blocks. The east and west sides of MLK have medical offices, emergency care, in-patient and out-patient facilities and parking structures. There are in-patient rooms on the 6th and 7th floors of the hospital building on the northeast corner of MLK and S 5th Street. All in-patient rooms are climate-controlled and no operable windows were identified during an onsite inspection of the side of the building that faces toward the alignment.

On the east side of MLK between S 6th Street and S 7th Street are multi-family and single family residences, and there is a medical office building complex on the west side of the street. Between S 7th and S 8th Streets are multi-family residences and a light industrial building on the east side of MLK. Several multi-family residences and a medical office building are located on the west side of the road.

From S 8th Street to S 15th Street, the east side of MLK is a mix of multi-family residential and commercial buildings. Churches are located on the corners of S 10th Street, S 13th Street, S 14th Street, and S 15th Street. Along this stretch of MLK, the west side of the street contains predominantly commercial uses. The Pathway Church and Peoples Park (which was determined through noise monitoring as not noise sensitive) are located at the corner of S 9th Street, and two multi-family residences are located above retail shops between S 10th and S 11th streets. From S 15th Street until the end of the TLE just north of S 19th Street, a mix of single-family and multi-family residences, medical office buildings, and commercial buildings are located on both sides of MLK. St. Joseph Medical Center is located on both sides of S "J" Street. It is over 200 feet east of the proposed alignment and is shielded from the alignment by a parking structure and other buildings. The Miles Memorial Church, Metro Parks Peoples Community Center, and Little Village Childcare Center are located between S 16th and S 17th streets.

3.1.2 Operations and Maintenance Facility Area

Land use in the area around the proposed operations and maintenance facility (OMF) is mostly industrial. A Best Western Hotel is located approximately 900 feet to the southwest of the facility.

Approximately 500 feet to the east is a pocket of four single-family homes, and one additional hotel is located approximately 1200 feet to the east of the site.

3.2 Existing Noise Environment

Sound Transit characterized the existing noise environment through onsite inspections and onsite noise monitoring. Monitoring was performed at 14 locations, including 5 long-term (24-hour or greater) and 9 short-term (15-minute) sites. The monitoring sites are shown on Exhibit 3-2, and detailed photos are provided in Appendix A. Long-term monitoring was performed at noise-sensitive locations representative of nearby properties. Short-term monitoring was also performed at other locations where long-term monitoring was not practical or where short-term data were used to supplement nearby long-term monitoring results. Sound Transit selected monitoring sites based on land use, existing noise sources, proximity and profile type, and the site's ability to represent nearby noise-sensitive land uses.

The FTA guidance manual (FTA, 2006) provides details on how parks are analyzed for noise in Chapter 3, Section 2, Application of Noise Impact Criteria, of the manual. The FTA assumes that parks are a special case, and how they are used and where they are located should be considered when considering whether or not a particular park, or an area in a park, is considered noise-sensitive. Parks that are used for outdoor recreation are typically not considered noise-sensitive. This includes parks with baseball diamonds, soccer fields, basketball courts, football fields, and other active recreation areas.

Noise-sensitive parks are defined as those where quiet is an essential element of their intended purpose, or places where it is important to avoid interference with activities such as speech, meditation, and reading. The existing noise levels at a park can indicate the sensitivity of its use. The parks along the project corridor were evaluated for consideration under the FTA criteria based on the park locations and existing noise levels. Measurements at two parks were taken and analyzed to establish that neither of the parks is noise-sensitive and to determine existing noise levels at nearby homes.

All noise measurements were taken in accordance with the American National Standards Institute (ANSI) procedures for community noise measurements and guidelines provided in the FTA guidance manual. Measurement locations were at least 5 feet from any solid structure to minimize acoustical reflections, and at a height of 5 feet off the ground as recommended by FTA and ANSI standards. The equipment used for noise monitoring included Bruel & Kjaer Type 2238 sound-level meters. The meters were calibrated before and after measurement periods using a sound-level calibrator. Complete system calibration is performed on an annual basis by an accredited testing laboratory. The laboratory system calibration is traceable to the National Institute of Standards and Technology (NIST). The systems meet or exceed the requirements for an ANSI Type 1 noise measurement system.

For long-term monitoring locations, the Ldn was calculated using logarithmic energy averaging for the 24-hour data with a 10-dBA penalty for noise measured between 10:00 p.m. and 7:00 a.m.

TACOMA LINK EXPANSION

NOISE AND VIBRATION MONITORING LOCATIONS

EXHIBIT 3-2

LEGEND

- Existing Stations
- Proposed Stations
- Existing Alignment
- Proposed Alignment
- Parks
- Existing Operations and Maintenance Facility Site
- Proposed Operations and Maintenance Facility Expansion Site
- Vibration Monitoring Location
- Noise Monitoring Location - Short Term
- Noise Monitoring Location - Long Term

0 0.125 0.25 0.5 Miles

SOUNDTRANSIT RIDE THE WAVE

For short-term monitoring locations, the projected Ldn levels were calculated using formulas in the FTA guidance manual and comparison with other nearby long-term noise monitoring sites.

The following section describes the existing noise environment. Exhibit 3-2 shows the proposed TLE alignment, noise monitoring locations, and vibration propagation test sites.

3.2.1 Operational Area

Four long-term and seven short-term monitoring locations were used to evaluate the area in which the TLE would operate. Noise levels along S Stadium Way and N "E" Street are dominated by both industrial and traffic noises. In the area facing the waterfront and Port of Tacoma, industrial noises predominate. On N 1st Street, traffic is the predominant source of noise. The higher Ldn at the YWCA, represented by receiver M-3, reflects this—the industrial sources operate throughout the night, whereas traffic volumes decrease during nighttime hours.

Noise levels where the proposed alignment would travel along Division Avenue and MLK are dominated by traffic noise. Noise levels throughout this area are fairly uniform. The Ldn in the Tacoma General Hospital neighborhood is 62 dBA, and it increases to 64 dBA at the southern end of the operational area.

Table 3-1 summarizes the noise monitoring effort for the TLE area of operations, including the monitoring location number, address, land use, and type of measurement. The peak-hour Leq is presented for all locations, but the 24-hour Ldn is presented only for Category 2 land uses, such as residences and hotels. Although the monitoring data are presented to the tenth of a dB, FTA recommends presenting the noise analysis data for impact analysis in whole numbers only.

3.2.2 Operations and Maintenance Facility Area

The OMF area had one long-term and two short-term monitoring locations. The first short-term noise monitoring site, M-12, was at the Best Western Hotel located at 2611 East E Street, just north of the Tacoma Dome and south of Freighthouse Square. Noise sources at this site include traffic on Interstate 5 (I-5) and other arterial roadways, along with various commercial and industrial activities. The Ldn was 69 dBA as a result of traffic on I-5 and nearby industrial sources that operate all day long.

The other two noise monitoring sites near residential uses are site M-2, located at the intersection of East K Street and E 26th Street, and site M-3, located in the back yard of the single-family residence at 1106 E 26th Street. Noise sources at both sites include Sounder Commuter Trains; freight train and Amtrak train activity in the rail yards to the north; traffic on I-5, Puyallup Avenue, and other arterial roadways; and various commercial and industrial activities. The Ldn at these homes ranged from 66 to 67 dBA.

Table 3-2 summarizes the noise monitoring effort for the area around the OMF, including the monitoring location number, address, land use and type of measurement.

TABLE 3-1
Noise Measurements

Monitoring Location [a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour [b] Leq in dBA)	Ldn (24-hour Ldn in dBA) [c]
M-1	Commerce Street behind 722 Pacific Avenue	Light industrial	Short-term	56.2	N/A [d]
M-2	S Stadium Way behind 539 Broadway	Commercial	Short-term	67.7	N/A [d]
M-3	YWCA, 405 Broadway	Multifamily residence	Long-term	70.8	71.1
M-4	Sidewalk at intersection of S Stadium Way and Division Avenue	Multifamily residence	Short-term	65.9	64.0
M-5	Stadium High School, 111 N "E" Street	School	Short-term	67.2	N/A [d]
M-6	Wright Park, across from N Yakima Avenue	Park	Short-term	62.5	N/A [d]
M-7	314 Martin Luther King Jr. Way	Hospital	Long-term	60.5	62.2
M-8	712 Martin Luther King Jr. Way	Multifamily residence	Long-term	63.7	62.7
M-9	900 Martin Luther King Jr. Way	Park	Short-term	62.5	N/A [d]
M-10	1423 Martin Luther King Jr. Way	Church	Short-term	63.6	N/A [d]
M-11	1720 Martin Luther King Jr. Way	Single-family residence	Long-term	63.7	64.1

Notes:
[a] Sites shown on Exhibit 3-2.
[b] Peak hour is the hour of the day with the highest noise level and/or the hour with the highest level of transit activity (typically sometime between 6:00 a.m. and 8:00 a.m., or 4:00 p.m. and 6:00 p.m. The Tacoma Link has maximum 10-minute headways, which was used for peak-hour noise analysis at Category 3 land uses.
[c] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA Transit Noise and Vibration Impact Assessment (FTA, 2006) and comparison to other nearby long-term noise monitoring sites.
[d] These sites were only measured for peak-hour Leq. No Ldn measure is required because these sites do not represent residential uses.
dBA = decibel with A-weighting
Ldn = 24 hour, time-averaged, A-weighted sound level
Leq = equivalent continuous sound level
N/A = not applicable

TABLE 3-2
Operations and Maintenance Facility Area Noise Measurements

Monitoring Location [a]	Address	Land Use Type	Type of Measurement	Leq (Peak-hour Leq in dBA)	Ldn (24-hour Ldn in dBA) [b]
M-12	Best Western, 2611 E Street	Hotel	Short-term	68	69
M-13	Public Right-of-Way next to 1106 E 26th Street	Single-family residence	Short- term	64	67
M-14	1109 E 26th Street	Single-family residence	Long-term	62	66

Notes:
[a] Sites shown on Exhibit 3-2.
[b] Projected Ldn levels for short-term monitoring sites have been calculated using formulas and methods in the FTA *Transit Noise and Vibration Impact Assessment* (FTA, 2006) and comparison to other nearby long-term noise monitoring sites.
dBA = decibel with A-weighting
Ldn = 24 hour, time-averaged, A-weighted sound level
Leq = equivalent continuous sound level

3.3 Existing Vibration Environment

Vibration in most areas is dominated by heavy truck traffic, buses, and other vehicles, with the highest levels occurring along rough roads or near roadways with potholes and other roadway blemishes. Typically, the vibration levels along most major and minor arterial roadways remain below 65 to 70 VdB, except in rare cases. Other sources of vibration include construction activities, railway

transportation, including freight rail, Amtrak and commuter trains, and existing Tacoma Link system vehicles.

For the TLE, vibration measurements were taken at two sites: site V1 on Stadium Way at Division Avenue, and site V2 on MLK, at the Tacoma General Hospital. Detailed photos of the testing sites are provided in Appendix A. The vibration measurements included measurement of the background (ambient) vibration levels, and testing for the propagation characteristics of the local area strata. Information on the ambient vibration and vibration propagation are provided in the following sections.

3.3.1 Ambient Vibration Levels

During the vibration testing, the system was allowed to capture the existing ambient, or background, vibration levels produced by existing traffic. Typical maximum RMS vibration levels on Stadium Way at Division Avenue reached 79.5 VdB, with average levels of 61 VdB over a 15-minute measurement period. Background vibration levels on N Broadway and Division Avenue were similar, with average vibration levels of 61 VdB and a maximum RMS level of 84.1 VdB. The maximum vibration levels occurred at the transducers nearest the roadway when a heavy vehicle passed by.

Along MLK, the exterior average vibration levels were measured at 60 VdB, with maximum levels of only 66 VdB. The lower maximum is likely the result of a smother roadway and slower speed in front of the hospital. Background vibration levels inside the hospital averaged 44 to 46 VdB, with maximum levels of 49 to 57 VdB. The lower interior vibration levels are a result of coupling loss and the size of the hospital foundation.

3.3.2 Vibration Propagation Characteristics

The propagation measurements are used to predict how vibration from the Tacoma Link system operations would be transmitted through the existing ground and what, if any, coupling loss may occur when the vibration meets the interface with the structure. A coupling loss is a reduction in the levels of vibration caused by the interface of a building's foundation with the surrounding ground. The general rule is that the heavier the building foundation, the greater the coupling loss as the vibration propagates from the ground into the building. Measurement of the coupling loss requires access to the interior of the building under consideration, with vibration measurement transducers being placed inside and outside the building for simultaneous vibration measurements. This process is more difficult than standard vibration propagation testing, and is normally only performed to finalize mitigation measures, or for special structures, such as a hospital or research center that has vibration-sensitive equipment.

The propagation measurements consist of dropping a heavy weight on the ground, measuring the force put into the ground by the weight, while simultaneously measuring the vibration response at several different distances from the impact site. As shown in Exhibit 3-3, accelerometers for measuring the ground vibration in the vertical direction are located in a line perpendicular to the impact line.

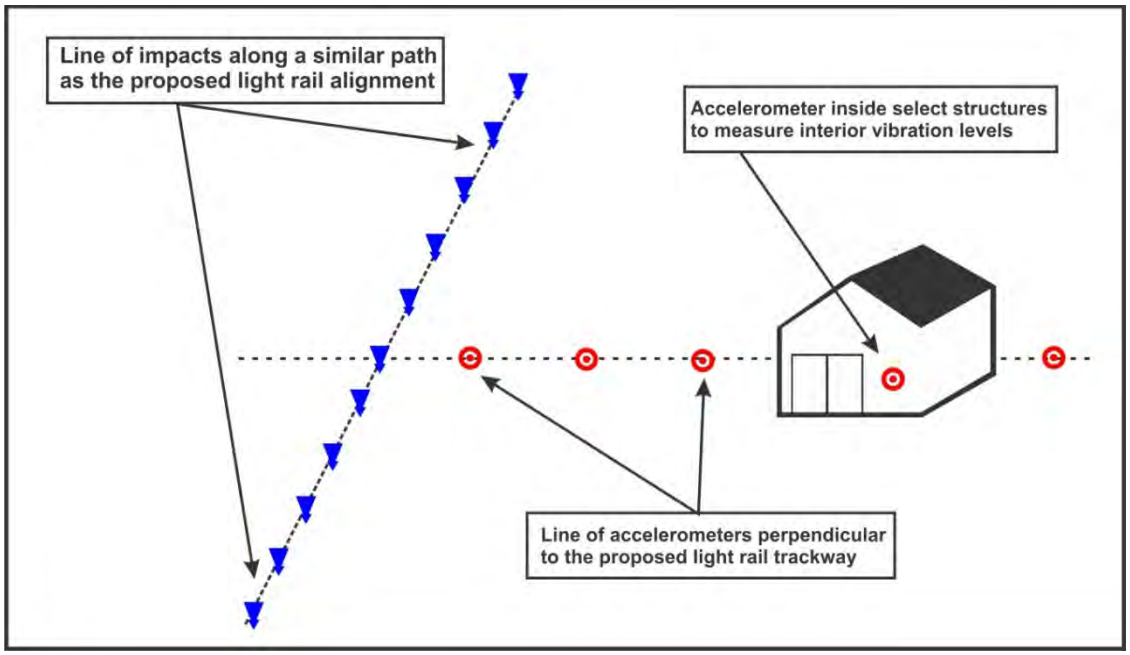
Line of impacts along a similar path as the proposed light rail alignment
Accelerometer inside select structures to measure interior vibration levels
Line of accelerometers perpendicular to the proposed light rail trackway

EXHIBIT 3-3
Schematic of Surface Vibration Propagation Testing

The number of accelerometers and the distances from the impact line vary depending on field conditions. For these tests, accelerometers were located at distances up to 125 feet from the impact line. All accelerometers were located outdoors, with the exception of two located inside the Tacoma General Hospital, and a third located on a terrace that was part of the hospital foundation. Impacts were performed at 11 positions along a path similar to the proposed Tacoma Link alignment at intervals of 15 feet.

The vibration propagation measurements from sites V1 and V2 were combined with measured vibration levels from the same make and model of Tacoma Link vehicles to arrive at vibration levels along the TLE corridor. The results are the vibration levels by distance from the trackway for the exterior of the buildings.

The one exception is the Tacoma General Hospital, where interior measurements were also performed and provide the measured interior vibration levels from TLE operations. Exhibits 3-4 and 3-5 provide the projected vibration levels from TLE operations.

The testing shows a peak in vibration at frequencies of 31.5 Hz to 50 Hz, and fairly efficient propagation out to 75 to 100 feet. The testing also revealed that the coupling loss at the Tacoma General Hospital was over 20 VdB at the peak frequencies, which is 7 to 10 VdB higher than the standard recommended coupling loss from the FTA manual (see three measurement on Exhibit 3-5). The higher coupling loss is likely due, in part, to the size of the hospital building. Details on the vibration projections are provided in Section 7.4.

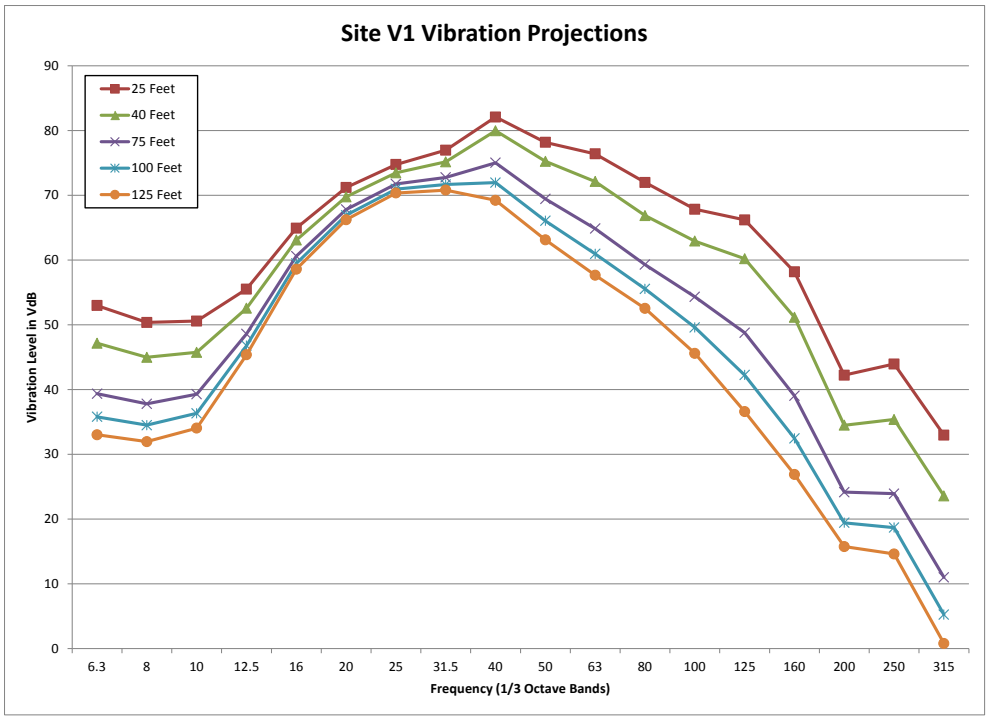

EXHIBIT 3-4
Vibration Projections at Site V1

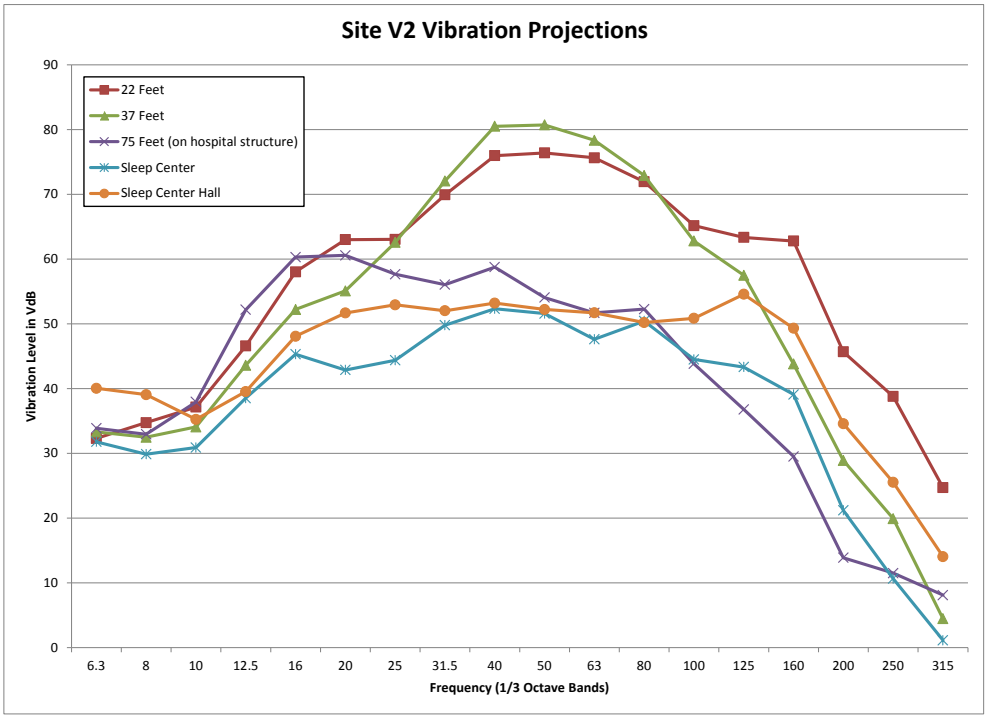

EXHIBIT 3-5
Vibration Projections at Site V2

4.0 Noise and Vibration Impact Criteria

This section describes the criteria used to assess noise and vibration impacts for the TLE project.

4.1 Transit Noise Impact Criteria

Noise impacts for the proposed project are determined based on the criteria defined in the FTA guidance manual (FTA, 2006). The FTA noise impact criteria are based on well-documented research on community reaction to noise and on change in noise exposure rated using a sliding scale. Although more transit noise is allowed in neighborhoods with high levels of existing noise, as existing noise levels increase, smaller increases in total noise exposure are allowed than in areas with lower existing noise levels. The FTA noise impact criteria group noise-sensitive land uses into the following three categories:

- Category 1: Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included in this category are recording studios and concert halls.
- Category 2: Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
- Category 3: Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds, and recreational facilities are also considered to be in this category. Certain historical sites and parks are also included, but their sensitivity to noise must be related to their defining characteristics. For example, parks with active recreational facilities are not normally considered noise-sensitive.

Ldn is used to characterize noise exposure for residential areas (Category 2). For other noise-sensitive land uses, such as outdoor amphitheaters and school buildings (Categories 1 and 3), the maximum 1-hour Leq during the facility's operating period is used. The two levels of impact included in the FTA criteria (severe and moderate) are as follows:

- Severe Impact: Project-generated noise in the severe impact range can be expected to cause a large percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation would normally be specified for severe impact areas unless there are truly extenuating circumstances that prevent mitigation.
- Moderate Impact: In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing noise level, the projected level of increase over existing noise levels, the types and numbers of

noise-sensitive land uses affected, the noise-sensitivity of the properties, the effectiveness of the mitigation measures, community views, and the cost of mitigating noise to more acceptable levels.

The FTA noise impact criteria are summarized in graphical form on Exhibit 4-1, which shows the existing noise exposure and the allowable noise exposure from the transit project that would cause either moderate or severe impact. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the TLE. Exhibit 4-2 expresses the same criteria in terms of the increase in total or cumulative noise that can occur in the overall noise environment before an impact occurs.

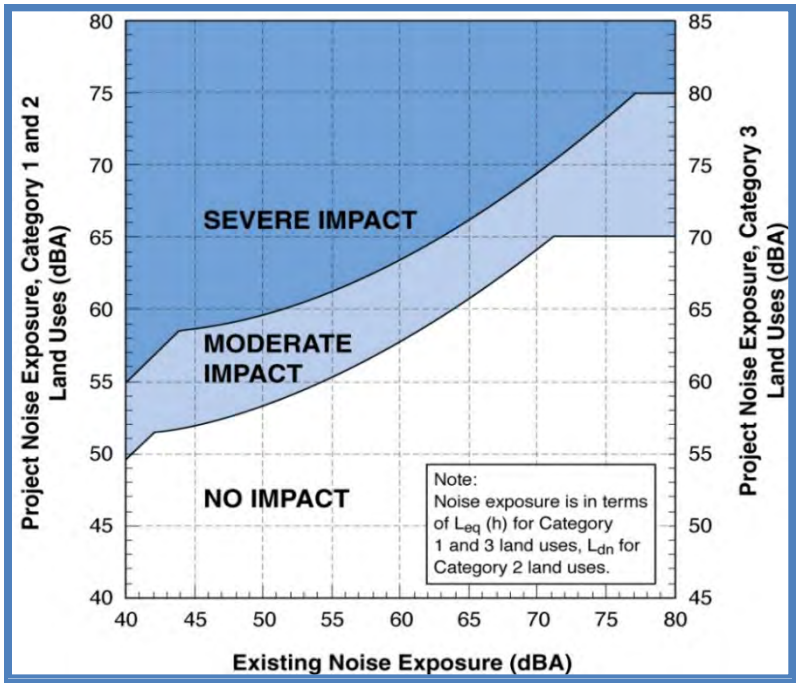

EXHIBIT 4-1
FTA Project Noise Impact Criteria

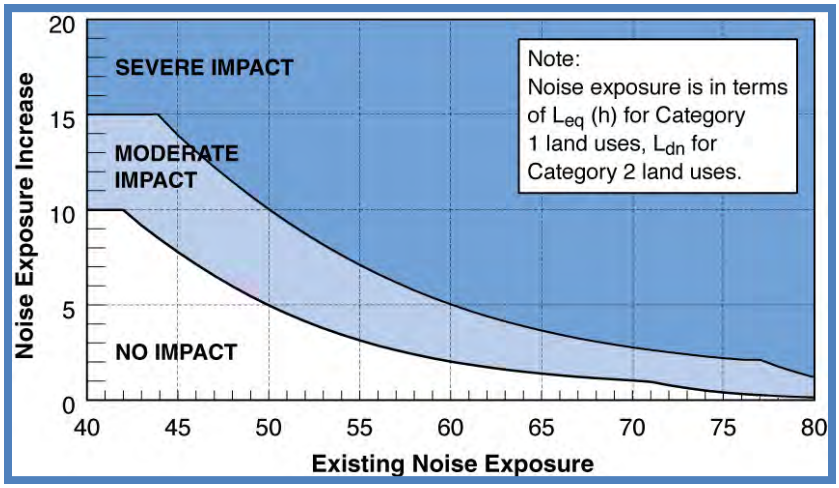

EXHIBIT 4-2
Increase in Cumulative Noise Exposure Allowed by FTA Criteria

The FTA guidance manual provides details on how parks are analyzed for noise in Chapter 3, Section 2, Application of Noise Impact Criteria, of the manual. The FTA assumes that parks are a special case, and how they are used and where they are located should be considered when deciding whether or not a particular park, or an area in a park, is considered noise-sensitive. Parks that are used for outdoor recreation are typically not considered noise-sensitive. This includes parks with baseball diamonds, soccer fields, basketball courts, football fields, and other active recreation areas.

Parks that are noise-sensitive would be those where quiet is an essential element in their intended purpose, or places where it is important to avoid interference with activities such as speech, meditation, and reading. The existing noise levels at a park can provide some indication of the sensitivity of its use. All parks along the project corridor were evaluated for consideration under the FTA criteria, and based on the park locations and existing noise levels, none met the requirements for noise sensitivity under the FTA Category 3 criteria.

4.2 State Regulations and Local Noise Ordinances

Noise analyses for high-capacity transportation projects funded by the FTA must be performed in accordance with the FTA guidelines found in the FTA guidance manual (2006). The FTA guidelines set forth the governing noise impact criteria for any such analysis; consequently, the project must meet the criteria defined in the FTA guidance. Construction noise and noise from ancillary facilities, such as maintenance facilities, are also governed by applicable state laws and regulations and local ordinances. In the case of the TLE, the City of Tacoma Municipal Code Chapter 8.122, Noise Enforcement, would be applicable to the OMF expansion, as well as to construction of the project, and is therefore considered in this analysis.

The other codes evaluated for this project include the WAC noise control regulation. WAC Chapter 173-60, Maximum Environmental Noise Levels, establishes maximum noise levels permissible in identified environments, including residential, commercial, industrial, and construction areas. However, WAC 173-60-110 provides that:

> *"The department conceives the function of noise abatement and control to be primarily the role of local government and intends actively to encourage local government to adopt measures for noise abatement and control. Wherever such measures are made effective and are being actively enforced, the department does not intend to engage directly in enforcement activities."*

Hence, the rules governing noise levels that are contained in WAC Chapter 173-60 do not apply when a local noise ordinance is in effect. Therefore, ordinances set forth in the City of Tacoma Municipal Code would be applicable to the operation of TLE ancillary facilities and project construction.

4.2.1 City of Tacoma

The City of Tacoma Municipal Code was examined for any noise ordinances or regulations that may be applicable to this project. Under Section 8.122.080 of the Tacoma Municipal Code, the increases in the ambient, or background, sound levels at any receiving property resulting from the operation of the

maintenance base are limited, as shown in Table 4-3. Hence, the Tacoma Municipal Code does not set absolute maximum noise levels, but instead stipulates increases over the existing ambient noise levels.

TABLE 4-3
City of Tacoma Maximum Permissible Increase in Sound Level above Ambient Sound Level

Time of Day	Outdoors	Indoors
7:00 a.m. to 10:00 p.m.	+10 dBA	+6 dBC
10:00 p.m. to 7:00 a.m.	+5 dBA	+3 dBC

Notes:
dBA = decibel with A-weighting
dBC = decibel with C-weighting

In addition, impulsive sounds cannot increase the total sound level by 15 dBA or more if there are nine or less impulses per hour between 7:00 a.m. and 10:00 p.m., or if there are three or less impulses per hour between the hours of 10:00 p.m. and 7:00 a.m. Impulsive sounds occurring more frequently than those stated are subject to the general maximum permissible increases set forth in Table 4-3.

Chapter 8.122 of the Tacoma Municipal Code would also apply to the construction of the proposed project. Under Sections 8.122.080.D and 8.122.090 of Chapter 8.122, sounds originating from construction work and construction devices (including backup alarms) are exempt from regulation under Section 8.122.080 of that Chapter between the hours of 7:00 a.m. and 9:00 p.m. during the week and 9:00 a.m. and 9:00 p.m. on the weekend. Work done outside of these hours must comply with the general prohibitions set forth in Chapter 8.122, which effectively means that a noise variance would be required from the City of Tacoma.

No other city or county noise regulations are applicable to construction of the project.

4.3 Vibration Impact Criteria

This section briefly defines criteria for vibration or groundborne noise impacts that might be produced by a transit system; these impacts are then evaluated as they apply to the TLE. The criteria for preventing building damage from construction-generated vibration are also discussed.

4.3.1 Vibration Impact Criteria

The FTA vibration impact criteria are based on land use and train passage frequency. These criteria generally apply to floors of structures. Table 4-4 lists the criteria for a general assessment of most land uses. The FTA vibration criteria apply primarily to residential floors (including hotels and other places where people sleep) and to institutional land uses. Commercial land uses are only considered when they contain vibration-sensitive uses, such as for medical offices or sensitive manufacturing equipment. The criteria applied to these locations depend on the sensitivity of the use. Some buildings, such as concert halls, recording studios, and theaters, can be particularly sensitive to vibration but do not fit into any of the three categories listed in Table 4-4. These buildings usually warrant special attention during the impact assessment. Table 4-5 provides the criteria for acceptable levels of groundborne floor vibration for special buildings.

TABLE 4-4
Groundborne Vibration and Noise Impact Criteria for General Assessment

Land Use Category	Groundborne Vibration Impact Levels (VdB re: 1 micro-inch/second)			Groundborne Noise Impact Levels (dB re: 20 micro-Pascals)		
	Frequent Events [a]	Occasional Events [b]	Infrequent Events [c]	Frequent Events [a]	Occasional Events [b]	Infrequent Events [c]
Category 1: Buildings where vibration would interfere with interior operations. Typically land uses include vibration-sensitive research and manufacturing, hospitals with vibration-sensitive equipment, and university research operations	65 [d]	65 [d]	65 [d]	N/A [e]	N/A [e]	N/A [e]
Category 2: Residences and buildings where people normally sleep	72	75	80	35	38	43
Category 3: Institutional land uses with primarily daytime use	75	78	83	40	43	48

Notes:
[a] "Frequent Events" are defined as more than 70 vibration events of the same source per day; most rapid transit projects fall into this category.
[b] "Occasional Events" are defined as between 30 and 70 vibration events of the same source per day; most commuter trunk lines have this many operations.
[c] "Infrequent Events" are defined as fewer than 30 vibration events of the same kind per day; this category includes most commuter rail branch lines.
[d] This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research requires detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the heating, ventilation, and air conditioning (HVAC) systems and stiffened floors.
[e] Not applicable. Vibration-sensitive equipment is generally not sensitive to groundborne noise.
dB = decibels
N/A = not applicable
VdB = vibration decibels

If a general assessment of vibration impacts indicates that the project would exceed the criteria in Table 4-4, then a detailed analysis considering the frequency spectra of the vibration is used to provide more information about the effects of the project. In many cases, it is desirable to conduct a detailed analysis without first conducting a general assessment, as was done for the TLE. The detailed assessment was preferred in the case of the TLE because it was critical to the track design specifications. By performing the detailed analysis first, the track installation process and rail boot type and size could be determined early in the project design process.

Table 4-6 provides vibration criteria for the detailed vibration analyses that were used for the TLE. The criteria in Table 4-6 apply to the 1/3-octave-band vibration velocity levels over the frequency range of 6.3 to 80 Hz. These detailed criteria are also used to assess vibration impacts at highly sensitive locations; however, no such highly sensitive locations have been identified along the project corridor. These criteria are also shown graphically in Exhibit 4-3.

TABLE 4-5
Vibration and Noise Impact Criteria for Special Buildings

Type of Building or Room [a]	Groundborne Vibration Impact Levels (VdB re: 1 micro-inch/second)		Groundborne Noise Impact Levels (dB re: 20 micro-Pascals)	
	Frequent Events [b]	Occasional or Infrequent Events [c]	Frequent Events [b]	Occasional or Infrequent Events [c]
Concert Halls	65	65	25	25

Television Studios	65	65	25	25
Recording Studios	65	65	25	25
Auditoriums	72	80	30	38
Theaters	72	80	35	43

Notes:
[a] If the building would rarely be occupied when trains are operating, then there is no need to consider impacts. As an example, consider locating a commuter rail line next to a concert hall; if no commuter trains would operate after 7 p.m., then trains should rarely interfere with the use of the hall.
[b] "Frequent Events" are defined as more than 70 vibration events per day; most transit projects fall into this category.
[c] "Occasional or Infrequent Events" are defined as fewer than 70 vibration events per day; this category includes most commuter rail systems.
dB = decibels
VdB = vibration decibels

TABLE 4-6
Vibration Criteria for Detailed Analysis

Criterion Curve	Maximum Lv (VdB)[a]	Description of Use
Workshop	90	Distinctly detectable vibration; appropriate to workshops and non-sensitive areas
Office	84	Detectable vibration; appropriate to offices and non-sensitive areas
Residential day	78	Barely detectable vibration; adequate for computer equipment and low-power optical microscopes (up to 20X)
Residential night, operating rooms, and sensitive hospital equipment	72	Vibration not detectable, but groundborne noise might be audible inside quiet rooms; suitable for medium-power optical microscopes (100X) and other equipment of low sensitivity
VC-A	66	Adequate for medium- to high-power optical microscopes (400X), microbalances, optical balances, and similar specialized equipment
VC-B	60	Adequate for high-power optical microscopes (1,000X) and inspection and lithography equipment up to 3 micron-line widths
VC-C	54	Appropriate for most lithography and inspection equipment to 1 micron detail size
VC-D	48	Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capability
VC-E	42	The most demanding criterion for extremely vibration-sensitive equipment

Notes:
[a] As measured in one-third-octave bands of frequency over the frequency range 8 to 80 Hz.
Lv = vibration velocity level
VC = vibration criteria
VdB = vibration decibels

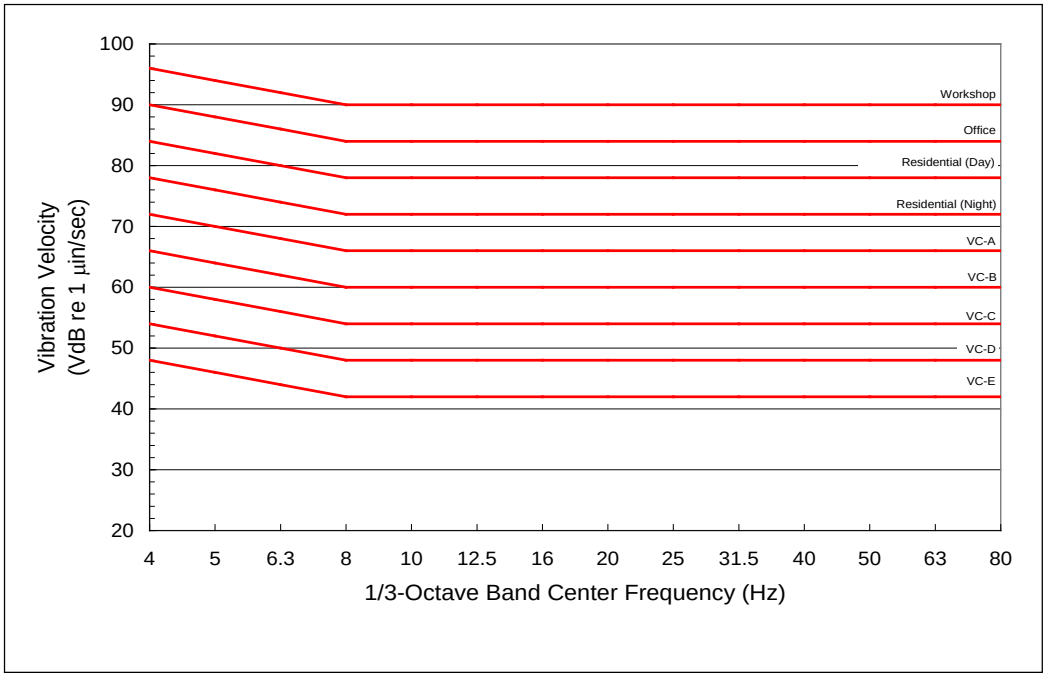

EXHIBIT 4-3
Vibration Criteria for Highly Sensitive Locations

4.3.2 Construction Vibration Criteria

There are no formal vibration criteria from the FTA or any state or local agencies. The primary concern regarding construction vibration relates to risk of damage. Vibration is generally assessed in terms of peak particle velocity (PPV) for risk of building damage. PPV is the appropriate metric for evaluating the potential for building damage and is often used when monitoring blasting and construction vibration because it relates to the stresses that are experienced by the buildings. Vibration damage risk thresholds to assess potential for damage from construction are based on criteria from *Effects of Vibration on Construction* (Swiss Consultants for Road Construction Association, 1992). There are no state or local ordinances concerning construction vibration limits. Table 4-7 presents the vibration damage risk thresholds for different building categories.

TABLE 4-7
Cosmetic Structural Damage Criteria

Building Category	PPV (in./sec)	Approximate Lv [a]
I. Reinforced concrete, steel, or timber (no plaster)	0.50	102
II. Engineered concrete and masonry (no plaster)	0.30	98
III. Non-engineered timber and masonry buildings	0.20	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Notes:
Source: FTA, 2006.

[a] Root mean square velocity level in decibels re 1 micro-in./sec.
in./sec. = inch per second
Lv = vibration velocity level
PPV = peak particle velocity

The damage risk criterion of 0.5-inch per second (in./sec.) PPV is appropriate for single- and multi-family residences along the alignment and the criterion of 0.12 in./sec. PPV is appropriate for extremely fragile buildings.

Construction vibration, unlike vibration from operations, has the potential to cause damage to structures at very close distances, from activities such as impact hammering and soil compacting. Generally, because of the short duration of construction vibration activities, annoyance is usually not an issue. The thresholds for damage for even the most sensitive buildings are 1 to 2 orders of magnitude higher than the criteria for annoyance from vibration.

5.0 Noise and Vibration Impact Analysis Methods

This section summarizes the models used to predict future noise and vibration levels for potential sources of community impact related to the TLE. These sources include Tacoma Link vehicles, OMF operations, and construction activities.

5.1 Noise Operational Measures

This section describes the assessment approach for noise related to operating the TLE. This includes noise from TLE operations, traffic noise (where applicable), ancillary facilities, and wheel squeal. Sound Transit employs several operational measures to maintain low noise and vibration levels for its transit rail vehicles. Table 5-1 lists the operational and maintenance measures that Sound Transit performs on a regular basis, and the benefit that each measure provides.

TABLE 5-1
System-wide Operational and Maintenance Measures

Operational Measure	System Benefit
Rail grinding, maintenance, and replacement	As rails wear, both noise and vibration levels from Tacoma Link Expansion operations can increase. By grinding or replacing worn rails or correcting improper track alignment, noise and vibration levels would remain at the projected levels.
Wheel truing and replacement	Wheel truing is a method of grinding down flat spots (commonly called wheel flats) on the vehicle wheels. Flat spots occur primarily because of hard braking. When flat spots occur, they can cause increases in both the noise and vibration levels produced by the Tacoma Link vehicles.
Vehicle maintenance	Vehicle maintenance includes performing scheduled and general maintenance on items such as air conditioning units, bearings, wheel skirts, and other mechanical units on the Tacoma Link vehicles. Keeping the mechanical systems on the Tacoma Link vehicles in top condition would also help to maintain the projected levels of noise and vibration.
Operator training	Operators would be trained to operate Tacoma Link vehicles at the speeds given in the operation plan that was used for the analysis and to avoid “hard-braking,” which can cause wheel flats and may also damage the track. Furthermore, by training operators to identify potential wheel flats and other mechanical problems with the Tacoma Link vehicles, proper maintenance can be performed in a timely manner.

5.2 Reference Tacoma Link Vehicle Noise Levels

Sound Transit modeled noise from TLE operations using the methods described in the FTA guidance manual. Input to the model included measured reference noise levels for the new Tacoma Link vehicles that are currently being used on the Tacoma Link system, including the Tacoma Link vehicle-mounted bells used at stations and in emergencies. The measured reference noise levels are 75 dBA Lmax for a single-car train traveling at 25 mph at a distance of 50 feet. The bells on the Tacoma Link vehicles produce 77 dBA at 100 feet; however, the vehicles are also equipped with flashing lights as a visual warning device, reducing the use of the bells for emergencies.

5.3 Alignment and Special Trackwork

A plan and profile of the proposed alignment, including the locations of special trackwork, such as crossovers, and typical speeds, were obtained from project design engineers. The current design calls for an embedded trackway, and the vibration testing was performed to aid in the design of the trackway along the corridor.

Track crossovers are mechanical devices that enable Tacoma Link vehicles to be guided from one track to another at a junction point. Crossovers have a gap in the rails that is necessary for the flange of the vehicle wheels to pass through at the location where the two tracks cross. As a wheel passes through the gap, there are increased noise and vibration levels. According to the FTA guidance manual, standard frogs, which are crossover components, can increase noise levels by as much as 6 dB.

Spring switch and movable point frogs solve the added noise and vibration problems by closing the gap on the rails. Flange-bearing frogs, another mitigation option, transfer the vehicle load from the wheel tread to the wheel flange and raise the Tacoma Link vehicle up and over the gap, reducing noise and vibration levels. Each of these types of frogs produces notably lower noise levels than standard frogs, and depending on the type of crossover and angle between the crossover and mainline track, special frogs, such as those described, can reduce noise levels between 4 and 5 dBA compared to a standard frog. For the TLE, the new crossovers would be located at the end of the alignment on MLK near S 19th Street and would be a special trackwork crossover and the second crossover is located at the tail track at the Tacoma Dome Station parking garage. In addition, because these crossover are located where the train speed would be very slow, any increases in noise levels as the train uses the crossover are not predicted to increase the overall operational noise by a measurable amount. The Tacoma Link vehicle-mounted bells used at stations are included in the noise analysis.

5.4 Operational Plan

The TLE operations schedule used in this analysis is the worst-case future operational plan. All TLE vehicles would operate as single car trains during all hours of operation.

The following TLE headways were used in this analysis:

- Early AM (4:30 a.m. to 6:36 a.m.): 20-minute headways, single-car trains
- Peak and Daytime (6:15 a.m. to 8:00 p.m.): 10-minute headways, single-car trains
- Evening (8:00 p.m. to 10:00 p.m.): 20-minute headways, single-car trains with the last train returning to the TLE maintenance base at 10:45 p.m.

5.5 Wheel Squeal and Wheel-flanging Noise

Wheel squeal is caused by the oscillation of the wheel against the rail on curved sections of rail. Research into methods of reducing wheel squeal noise, including using nonoil-based lubricants (such as water) and friction modifiers, has found that such methods effectively reduce or eliminate wheel squeal. The lubricants can be applied by personnel working trackside, or by an automated applicator either on the trains or mounted along the trackway. It is a general policy of Sound Transit to install or

prepare for lubrication on any curves with a radius of less than 600 feet near noise-sensitive properties. If, after system operation begins, wheel squeal is identified, train-mounted or wayside lubricators would be used to mitigate the squeal.

The only curves that have a tight radius, and therefore may need squeal lubrication, are:

- The curve at Stadium Way at N 1st Street
- The curve from Division Avenue to MLK

5.6 Tacoma Link Noise Projections

Noise impacts that would result from the TLE were determined through the following approach:

1. Sound Transit performed a land use survey of potential noise-sensitive receptors near the proposed alignment. This process involved site visits and use of area land use maps and information from other project team members.
2. Sound Transit conducted long-term (multi-day) and short-term (15- to 30-minute) noise monitoring to establish existing noise levels for the potentially affected area. Ambient noise monitoring was taken at 14 locations along the corridor.
3. Existing ambient sound levels were used to determine the noise impact criteria. The FTA criteria for noise impact are based on the existing noise level and land use (see section 4.1).
4. Projections of project noise levels were made based on train speed and distance of receiver from tracks.
5. Sound Transit evaluated projections with respect to impact thresholds to determine if a receiver would be affected by TLE operations.
6. Where noise impacts were identified, mitigation was considered. Any mitigation recommendations followed the Sound Transit Noise Mitigation Policy.

5.7 Operations and Maintenance Facility Noise Projections

Noise and vibration from OMF operations were modeled using the methods described in the FTA guidance manual (FTA, 2006). The modeling results were compared to criteria contained in the FTA guidance manual (2006) and City of Tacoma noise ordinances. The proposed OMF would enable Sound Transit to provide service and inspection functions for supporting the TLE fleet of vehicles The OMF would be used to store, maintain, and dispatch vehicles for daily service. Activities at the OMF would include preventive maintenance inspections, light maintenance, emergency maintenance, interior vehicle cleaning, and exterior vehicle washing.

The proposed OMF expansion would have space for employee parking, operations staff offices, maintenance staff offices, dispatcher work stations, an employee report room, and areas with lockers, showers, and restrooms for both operators and maintenance personnel. The following sections provide the assumptions that were used to predict noise and vibration levels associated with the project.

The noise impact assessment was performed using the FTA guidance and City of Tacoma noise ordinances for all receivers near the site, including other commercial and industrial uses (per city and state code) and single-family residences located along E 26th Street. The analysis included noise from general maintenance operations, cleaning of trains, the arrival and departure of trains at the OMF, vehicle movement, and ancillary equipment, including power substation.

The analysis used reference noise levels for operation of a maintenance base taken from the FTA guidance manual (2006). The operational analysis assumed that the facility would operate 24 hours a day. Major operational assumptions include:

- The facility would have storage for approximately eight Tacoma Link vehicles.
- The car wash would be located behind the storage tracks, and as a worst case, all car washing is assumed to occur during nighttime hours.
- Although wheel squeal can be an issue at a large OMF with circular train routing, no wheel squeal is predicted at this facility because of the simpler layout with no circular routing, low speeds of 5 mph for vehicles operating in the OMF, and the large-radius curves of the storage tracks.
- In addition, the slow speed on the storage tracks would also reduce any impact noise associated with crossovers at the facility. Only the crossovers on the access tracks were included in the analysis.
- Noise from general maintenance activities inside the shop building would include use of hand tools, continuous operation of compressors and other mechanical equipment, and intermittent operation of equipment such as overhead cranes, vehicle lifts, and the wheel trues. The equipment would all be located inside the maintenance shop. The predictions of the noise that would be emitted from the shop are based on measurement information from the FTA guidance manual.
- Some equipment in the shop, such as the vehicle lifts and overhead cranes, may be equipped with alarms to alert workers before they are used. In the design of the shop facility, the use of these alarms would be minimized and any alarms used would be designed to provide appropriate warning for shop personnel.
- There would be limited vehicle movements inside the yard. Once a train enters the storage yard, it would be inspected by maintenance crews, and any repairs or preventative maintenance would be performed. Then the train would be cleaned and parked, and would usually stay in place until it goes back into revenue service. Movements within the yard could include shuttling vehicles to the shop and to the car wash and cleaning station.
- The noise from the traction power substations in the maintenance yard would be a maximum of 49 dBA at 50 feet, and is not expected to be an issue.
- Activities at the cleaning station would include vacuuming and hand-cleaning of the vehicle interior. This is assumed to be an insignificant noise source.

Using the above assumptions, the 24-hour Ldn, peak nighttime hourly Leq, and maximum overall noise level (Lmax) were calculated and used to predict potential noise impacts. The 24-hour Ldn was compared to the appropriate FTA noise criteria from Section 4.1. The peak-hour Leq and Lmax were used to show compliance with the local noise control ordinance. The worst-case nighttime hours are during the deployment of the vehicles around 4:30 a.m. to begin revenue service.

5.8 Vibration Impact Analysis Methods

This section summarizes the models, methods, and assumptions used to predict future vibration velocity levels for potential sources of community impact related to the TLE. These sources include TLE operation and construction activities. The Tacoma Link vehicle wheels and track are assumed to be maintained in good condition with regular wheel truing and rail grinding, in accordance with Sound Transit maintenance procedures.

The predictions of groundborne vibration for this study follow the Detailed Vibration Assessment procedure of the FTA guidance manual (2006). This is an entirely empirical method based on testing the vibration propagation characteristics of the soil in the project corridor and measuring the vibration characteristics of a similar vehicle. As discussed in Section 3.3, vibration propagation tests were performed at two locations in the proposed corridor for the TLE project. The quantity derived from the propagation tests, along with measurements of the vibration characteristics of a similar vehicle, were combined to predict vibration levels versus distance from the trackway based on a directly embedded trackway.

For areas where vibration levels may meet or exceed the FTA criteria, the track type was modified to a design that would reduce the overall vibration levels transmitted into the ground and would maintain vibration levels below the FTA criteria. Additional testing may be performed during final design to further refine the track design that would be used along those parts of the corridor where vibration levels could meet or exceed the FTA criteria. Locations where the vibration-reducing track design is necessary are identified in Section 7.4, Vibration Impact Analysis.

6.0 Future No Build Conditions

With or without the TLE, traffic on Stadium Way, Division Avenue, MLK Jr. Way, and other ancillary roadways would continue to increase as population and density increase. For most roadways, an increase in traffic volume of less than 1 to 2 percent per year can be expected, depending on development and area growth. Traffic noise is currently the dominant source of noise for receivers along the corridor, and would continue to be the main source in the future, even without the construction of the TLE project. Overall, noise levels would be expected to increase by 1 to 2 dBA over the next 20 years, an increase that is not normally perceivable to an average person.

7.0 Future Build Conditions

Sound Transit performed a detailed noise impact assessment based on the criteria discussed in Section 4.0 and on the methods and projections described in Section 5.0 of this report. Detailed noise analysis sheets, including complete tabulated data of the project parcel identification, existing noise levels, project noise levels, criteria, and other information, are provided in Appendix B. Sheets with similar information for vibration are provided in Appendix C.

7.1 Transit Noise Impact Analysis

Sound Transit based the evaluation of the potential environmental noise impacts from the project alternative on the change in the environmental noise level that would be caused by the project and the number of dwelling units potentially affected by project noise. The transit noise methodology, as discussed in Section 5.0 of this report, is consistent with the FTA guidance manual (FTA, 2006). Also, as defined in Sections 5.3 and 5.4, special trackwork, including crossovers, along with Tacoma Link vehicle mounted bells used at stations, are included in the analysis. Sound Transit also applied the FTA noise assessment methodology and the City of Tacoma noise ordinance provision requirements to the OMF. The remainder of this section provides the results of the noise analysis.

A total of 162 properties were evaluated for Tacoma Link operational noise impacts. Near the beginning of the corridor, across from the station, there are two multi-family residences, and north of S 7th Avenue there are several multi-family buildings located on Broadway Street, overlooking the alignment along S Stadium Way. Operational Ldn noise levels from the TLE along this section of the corridor ranged from 54 to 60 dBA Ldn, which are 2 dB to 12 dB below the FTA criteria. The Rescue Mission, located at 702 Pacific Avenue, is predicted to receive operational noise levels of 59 dBA, which is 4 dB below the FTA criterion for that location. Overall, no noise impacts are predicted along S Stadium Way. Noise levels from the TLE at the Stadium High School are predicted at 56 dBA Leq during peak hour, which is notably less than the FTA criterion of 68 dBA for an institutional land use. The 56 dBA Leq from Tacoma Link operations is also well below the FTA criterion at the Stadium High School Annex, which includes a performing arts center and a gymnasium.

Along Division Avenue, noise-sensitive land uses consist of one multi-family building and several churches, none of which are predicted to have noise impacts. Where the alignment transitions to MLK Jr. Way, a noise impact was identified at the exterior face of the Tacoma General Hospital; however, this is an exterior noise level of 60 dBA, which is only 1 dB over the FTA criterion of 59 dBA for the hospital. More importantly, the exterior to interior transmission loss is predicted to be sufficient to maintain interior noise levels well below Sound Transit's interior 45 dBA Ldn criterion for sleeping areas. In fact, because of the non-operable windows on the hospital's patient rooms, the exterior noise level of 60 dBA Ldn would be predicted to be below 30 dB inside any of the patient rooms, and therefore well below the 45 dBA Ldn criterion used for sleeping areas. Finally, for reference, 30 dBA is well below the noise level typically found in a rural bedroom or quiet library.

As the alignment travels down MLK, land uses include residential, institutional, and some medical properties. The existing Ldn of 62 to 64 Ldn at most residential uses is sufficiently high that the project noise contribution would not exceed the FTA criteria, and no noise impacts were predicted along this part of the corridor. For Category 2 uses, operational noise levels would range from 44 to 60 dBA Ldn, with residences along MLK Jr. Way 1 to 4 dB below the FTA criteria. For churches and medical buildings (FTA Category 3 uses), the operational noise levels would range from 45 to 57 dBA Leq. Predicted noise levels at these institutional uses and medical buildings are all 9 dB or more below the FTA criteria for Category 3 land uses.

7.2 Operations and Maintenance Facility Impact Analysis

The OMF impacts analysis was performed using the information from Section 5.7, along with input from Sound Transit on operations at the existing facility. Although the facility would be expanded to accommodate the added trains necessary for the TLE, the overall noise-producing activities and noise levels would remain similar to current noise levels. The reference noise levels for operation of the expanded OMF are 62.4 dBA Leq at 50 feet during typical daytime operation, with a 24-hour Ldn, which assumes 24-hour-per-day operation, of 68.8 dBA Ldn. Using these two reference noise levels, noise levels at the nearest noise-sensitive properties were calculated.

The nearest residential land use to the facility is a single-family residence located at 1109 E 26th Street, which is approximately 580 feet from the expanded facility. The noise levels from OMF operations at this distance, with no additional reduction for ground effects or structural shielding, is 41 dBA Leq during peak hours and 47 dBA Ldn, for a 24-hour period, and the corresponding FTA criterion for the home is 53 dBA. Given the existing measured noise levels at this home of 62 dBA Leq during daytime hours, and a 24-hour Ldn of 66 dBA, the operation of the OMF would not result in any noise impacts at this or any other residential properties located in the vicinity of the facility. Furthermore, because the predicted OMF noise levels are more than 10 dB lower than the existing ambient level, the OMF would also be in compliance with the City of Tacoma noise ordinance.

7.3 Construction Noise Impact Analysis

The construction noise analysis considers the temporary noise impacts that construction would potentially cause in the project vicinity. These impacts would end when project construction is completed. Noise related to construction would result from the operation of heavy equipment needed to construct various project components, including stations. The contractor would be required to adhere to local ordinances regulating noise, as discussed in Section 4.3. Construction activities outside normal weekday daytime hours would require a noise variance from the City of Tacoma if regulatory noise levels are exceeded.

Equipment required to complete the TLE would include construction equipment typically used for transportation construction projects. Table 7-1 lists the typical equipment used for this type of project, the activities it would be used for, and the corresponding maximum noise levels that would be produced when measured at 50 feet from the sources under normal use.

TABLE 7-1
Construction Equipment and Reference Noise Levels

Equipment	Expected Project Use	Lmax [a, b] (dBA)
Air compressors	Pneumatic tools and general maintenance (all phases)	70 to 76
Backhoe	General construction and yard work	78 to 82
Concrete pump	Pumping concrete	78 to 82
Concrete saws	Concrete removal and utilities access	75 to 80
Crane	Materials handling: removal and replacement	78 to 84
Excavator	General construction and materials handling	82 to 88
Forklifts	Staging area work and hauling materials	72
Haul trucks	Materials handling: general hauling	86
Jackhammers	Pavement removal	74 to 82
Loader	General construction and materials handling	86
Pavers	Roadway paving	88
Pile-drivers	Support for structure and hillside	99 to 105
Power plants	General construction use: nighttime work	72
Pumps	General construction use: water removal	62
Pneumatic tools	Miscellaneous construction work	78 to 86
Tractor trailers	Material removal and delivery	86
Utility trucks	General project work	72
Vibratory equipment	Shoring up hillside to prevent slides and soil compacting	82 to 88
Welders	General project work	76

Notes:
[a] Typical maximum noise level under normal operation as measured at 50 feet from the noise source.
[b] Noise levels presented are based on measured data from the Portland Light Rail and I-5 Preservation and Hawthorne Bridge construction projects and other measured data, as well as U.S. Department of Transportation construction noise documentation and other construction noise sources.
dBA = A-weighted decibels
Lmax = maximum overall noise level

7.3.1 Construction Noise

Several construction phases would be required to complete the TLE. The FHWA Roadway Construction Noise Model (FHWA, 2006) was used to provide an estimate of the project construction noise levels, as well as to predict the maximum noise levels for several different construction phases. The analysis assumes the worst-case average and maximum noise levels based on the three major types of construction described below and shown in Table 7-2. The actual noise levels experienced during construction would generally be lower than those described in Table 7-2 because these are the maximum noise levels for each activity. The noise levels presented here are for short periods of maximum construction activity and would occur for a limited period of time.

TABLE 7-2
Noise Levels for Typical Construction Phases [a]

Scenario [b]	Equipment [c]	Lmax [d]	Leq [e]
Demolition, site preparation, and utilities relocation	Air compressors, backhoes, concrete pumps, cranes, excavators, forklifts, haul trucks, loaders, pumps, power plants, service trucks, tractor trailers, utility trucks, and vibratory equipment	88	87
Track installation, system integration, station construction and paving activities	Air compressors, backhoes, cement mixers, concrete pumps, cranes, forklifts, haul trucks, loaders, pavers, pumps, power plants, service trucks, tractor trailers, utility trucks, vibratory equipment, and welders	88	88
Miscellaneous activities	Air compressors, backhoes, cranes, forklifts, haul trucks, loaders, pumps, service trucks, tractor trailers, utility trucks, and welders	86	83

Notes:
[a] Combined worst-case noise levels for all equipment at a distance of 50 feet from work site.
[b] Operational conditions under which the noise levels are projected.
[c] Normal equipment in operation under the given scenario.
[d] Lmax (dBA) is the highest maximum noise level for the construction equipment listed under the given scenario.
[e] Leq (dBA) is a 1-hour energy average noise emission for construction equipment operating under the given scenario.
Leq = equivalent sound level
Lmax = maximum overall noise level

7.3.2 Demolition, Site Preparation, and Utilities Relocation Construction Noise

Major noise-producing equipment in use during this stage of TLE construction could include saw cutters, concrete pumps, cranes, excavators, haul trucks, loaders, tractor-trailers, and vibratory equipment. Maximum noise levels could reach 83 dBA to 88 dBA at the nearest residences (i.e., within 50 to 100 feet) for normal construction activities during this phase. Other less-notable noise-producing equipment expected during this phase would include backhoes, air compressors, forklifts, pumps, power plants, service trucks, and utility trucks.

7.3.3 Track Installation, Station Construction and Paving Activities

The loudest noise sources in use during this phase of construction would include cement mixers, concrete pumps, cranes, pavers, haul trucks, and tractor-trailers. The cement mixers, cranes, and concrete pumps would be required for construction of the trackway and stations. The pavers and haul trucks would be used to provide the final surface on the trackway and roadways modified during other phases of construction. Maximum noise levels are predicted to reach 86 to 88 dBA at the closest receiver locations.

7.3.4 Miscellaneous Activities

Following heavy construction, general construction would still be required, such as installation of signage, roadway striping, and communication and power systems, as well as other miscellaneous activities. These less-intensive activities are not expected to produce noise levels above 80 dBA at 50 feet except during rare occasions, and even then only for short periods of time when maximum noise levels could reach 86 dBA Lmax at 50 feet. Using the information in Table 7-2, typical construction noise levels were projected for several distances from the project work area. Exhibit 7-1 is a graph of general construction noise level versus distance for phases of construction.

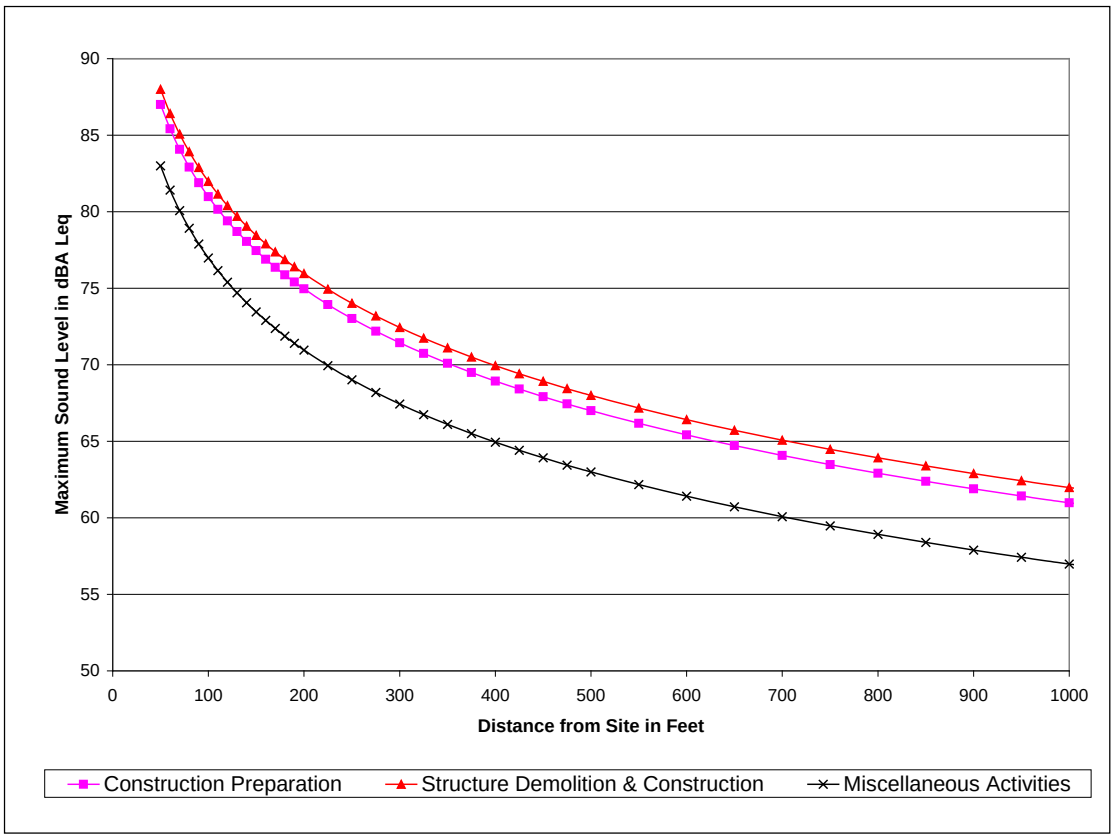

EXHIBIT 7-1
Maximum Noise Level versus Distance for Typical Construction Phases

7.3.5 Nighttime Construction

Some construction activities might be required during nighttime hours because of the nature of the construction or to avoid daytime traffic impacts or impacts to some adjacent land uses. In order to perform construction at night, a noise variance from the local governing agency would be required. If nighttime construction is deemed necessary, Sound Transit or the contractor would work with each governing agency to obtain any necessary noise variance specific to project construction.

7.4 Vibration Impact Analysis

Sound Transit performed a detailed vibration impact assessment based on the criteria discussed in Section 4.0 and on the methods and projections described in Section 5.0 of this report. The analysis was performed in three phases:

1. Perform a base analysis to determine any exterior site that may have vibration levels at or above the FTA criteria.
2. Review site with vibration level at, or above, the criteria and apply a general coupling loss for the structure based on information from the FTA, but remaining conservative in the application of coupling loss to make sure all vibration levels would not exceed the projections.

3. For areas with vibration levels that still have the potential to meet or exceed the FTA criteria, revise the track installation procedure to include a vibration-dampening resilient boot system that would reduce vibration levels to below the criteria, and identify those sites where the special installation process would be needed.

The results of these vibration projections are provided in the following two sections.

7.4.1 Operational Area

Vibration levels along S Stadium Way and N 1st Street were projected using the propagation data testing site V1 as a basis for the analysis. The measured vibration level projections for TLE operations, assuming a standard directly embedded track design, are shown on Exhibit 3-4. Based on these projections, exterior vibration levels could meet or exceed the FTA criteria at a distance of 75 to 100 feet from the trackway, and vibration levels are predicted to exceed the FTA criteria at the building exterior for a number of receivers. However, with the building coupling loss, which is a reduction in the vibration levels where the building foundation meets the existing ground, vibration levels at the residences, schools, and other vibration-sensitive properties along Stadium Way, N “E” Street, N 1st Street, and Division Avenue all have predicted vibration levels that are below the FTA criteria. With the predicted coupling loss, all of the structures along these roads have vibration levels below 68 VdB, with FTA criteria ranging from 72 to 84 VdB. Additional vibration propagation testing may be performed during final design to verify the coupling loss factors and better design the track; however, no vibration impacts are predicted in this portion of the TLE corridor.

There are 28 single- and multi-family residences along MLK that could have vibration levels between 72 and 75 VdB, assuming minimal coupling loss and a directly embedded trackway. The FTA criteria for vibration impacts at these residences is 72 VdB. The FTA guidance manual assumes that most single-family residences would have some coupling loss, typically up to 5 VdB, which would eliminate all the potential impacts. However, to maintain a conservative analysis, this study assumes that there would be no coupling loss for small single-family residences; instead, the track design would be modified to provide an extra 5 to 8 VdB of vibration reduction.

Special track design is included as part of the project along sections of MLK to reduce vibration levels to within the FTA criteria. There are two types of track design being considered for these areas. The first design uses shredded rubber tires on a concrete slab, with the tracks installed on a separate concrete slab or standard concrete ties that are placed on top of the shredded rubber; this is commonly called a tire-derived aggregate (TDA) installation. With this type of design, the Tacoma Link vehicles’ vibrations are absorbed by the TDA, and vibration levels can be reduced by 5 VdB or more, depending on the thickness of the layer of TDA.

The second type of design uses a resilient rail boot. A cross-view of this design is provided in Exhibit 7-2. Although the exhibit uses information from CDM-QTrack, other manufacturers’ products that meet the requirements could be considered and used for this design. Other vibration-reducing measures besides the TDA and resilient rail boot could also be considered during final design. Sound Transit will perform additional vibration testing and analysis during final design to identify those

locations where special trackwork is needed and to refine the type of vibration-reducing special trackwork to be included in system design and construction. If, during the final testing, vibration levels are determined to be below the FTA criteria without using a special design, then a normal embedded track type would be used. Appendix C summarizes the vibration projections and current sites where special trackwork is assumed.

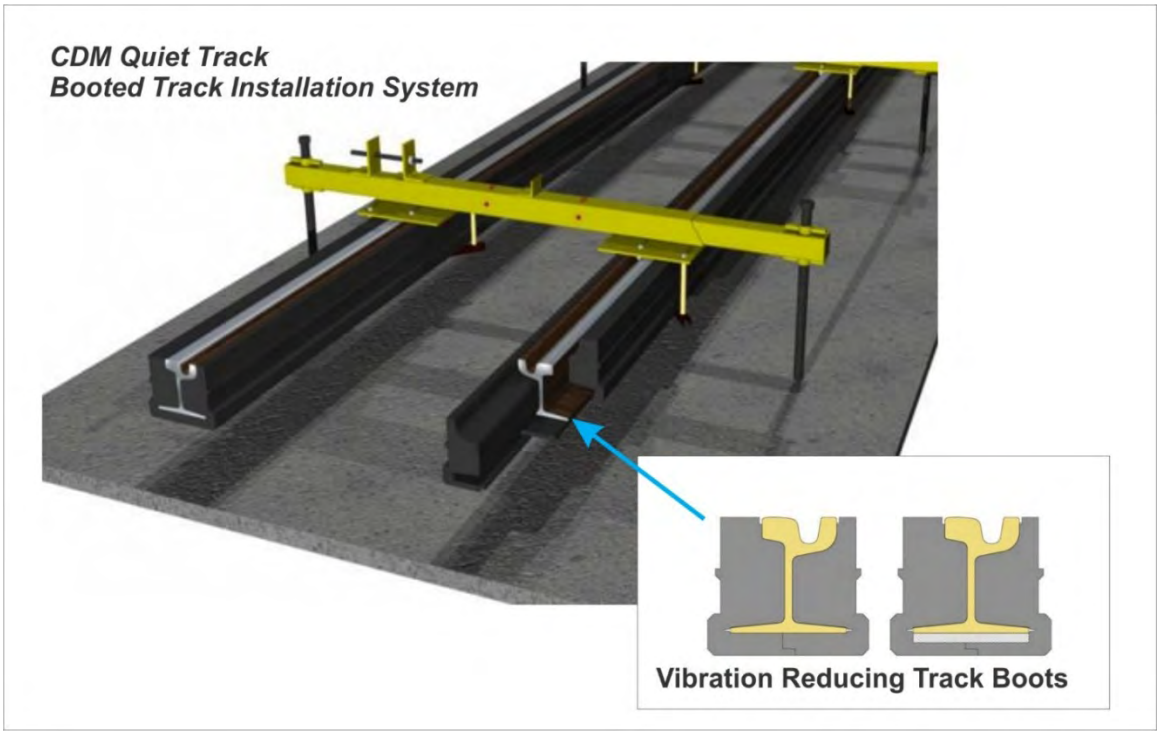

EXHIBIT 7-2
Special Trackway Sample

7.4.2 Operations and Maintenance Facility

The nearest structures to the OMF are industrial uses on E 25th Street, which are as close as approximately 80 feet from the maintenance tracks. All vibration-sensitive uses, such as residences and commercial land uses, are over 150 feet from the OMF and therefore would have vibration levels well below 72 VdB. Because there are no vibration impact criteria for industrial uses, and all vibration sensitive uses are well over 150 feet from the OMF tracks, no OMF-related vibration impacts are predicted.

7.5 Construction Vibration Impact Analysis

Vibration associated with general construction activities can result in increased vibration levels. Project-related vibration sources include excavators, haul trucks, flat-bed tractor-trailers, backhoes, cranes, and jackhammers. In addition, pile driving is also expected for the OMF expansions.

The vibration sources associated with the project, even though they may be noticeable to residents when construction is nearby, are not expected to cause any structural damage. The following two sections discuss vibration related to construction of the new Tacoma Link expansion and construction of the expanded OMF facility.

7.5.1 Construction of the Tacoma Link Expansion

Vibration levels for construction activities are projected to be the highest during demolition activities and soil compacting. Major construction equipment that would be used during demolition includes excavators, haul trucks, backhoes, jackhammers, and cranes. Based on information from the U.S. Bureau of Mines, it typically takes vibration levels in excess of 0.5 in./sec. to cause cosmetic damage to plaster walls, and 0.75 in./sec. for cosmetic damage to drywall. Vibration levels from project construction are projected to remain below 0.5 in./sec. at residences along the project corridor because of the distance between the work zones and structures. Based on this, there is only a minimal potential for any structural damage during construction, and only for structures located within 25 to 50 feet of the work zones. Table 7-3 provides typical vibration levels for several common types of construction equipment.

TABLE 7-3
Distance to Construction Vibration Impact Thresholds

Equipment	Conditions	Peak Particle Velocity at 25 feet (in./sec.)	Vibration Level in VdB at 25 feet (re 1 micro-in./sec.)
Large Bulldozer	Normal operations	0.089	87
Loaded haul trucks	Normal operations	0.076	86
Jackhammer	Normal operations	0.035	79
Small Bulldozer	Normal operations	0.003	58
Vibratory Roller	Normal operations	0.210	94

Source: FTA, 2006.
in./sec. = inch(es) per second
VdB = vibration decibels

7.5.2 Construction of the OMF Expansion

The majority of the construction at the OMF would be similar to the construction of the Tacoma Link expansion described above. Construction vibration would include similar activities and vibration levels for most activities for construction of the expanded facility.

The highest vibration levels at the OMF are expected to result from pile driving that would be used to install the piles supporting the expanded facility. Based on the FTA guidance (2006), vibration levels from impact pile driving can reach 1.5 in./sec. at 25 feet, with typical levels of 0.6 in./sec. at 25 feet. Use of a sonic pile driver would produce lower vibration levels, with maximum levels of 0.7 in./sec. at 25 feet, and typical levels of 0.17 in./sec. at 25 feet. Additional information on the vibration levels from pile driving would be obtained from test piles that are being driven as part of the Tacoma Trestle Project. Data from this testing would be used to assist with the vibration analysis for the Tacoma Link OMF expansion.

8.0 Noise and Vibration Mitigation

8.1 Noise Mitigation

This section provides a summary of noise impacts from operation or construction, and provides noise mitigation where appropriate and/or required.

8.1.1 Operational Noise Mitigation

One TLE operational noise impact was identified at the exterior face of the Tacoma General Hospital. Building insulation would customarily be the recommended mitigation measure for that impact. However, the exterior to interior transmission loss is predicted to be sufficient to maintain interior noise levels well below 45 dBA Ldn, which would result in noise levels below the FTA criterion of 59 dBA for the hospital. However, if wheel squeal is identified during pre-revenue service, or during operation, track lubrication or other measures would be implemented.

8.1.2 Operations and Maintenance Facility Noise Mitigation

No OMF noise impacts were identified, and therefore no noise mitigation is recommended as part of the project.

8.1.3 Construction Noise Mitigation

Potential construction noise impacts can be reduced with operational methods and scheduling, equipment choice, and acoustical treatments. When required, Sound Transit or its contractor would seek the appropriate noise variance from the local jurisdiction. Noise control mitigation to meet local regulatory requirements, noise ordinances, and permit or variance conditions would be required. These measures could include:

- Install construction site noise barrier or wall by noise-sensitive receivers where appropriate.
- Use smart back-up alarms during nighttime work that automatically adjust, or lower the alarm level or tone based on the background noise level, or switch off back-up alarms and replace with spotters.
- Use low-noise emission equipment.
- Implement noise-deadening measures for truck loading and operations.
- Monitor and maintain equipment to meet noise limits.
- Use lined or covered storage bins, conveyors, and chutes with sound-deadening material.
- Use acoustic enclosures, shields, or shrouds for equipment and facilities.
- Install high-grade engine exhaust silencers and engine-casing sound insulation.
- Prohibit aboveground jack hammering and impact pile driving during nighttime hours.
- Minimize the use of generators or use whisper-quiet generators to power equipment.

- Limit use of public address systems.
- Use movable noise barriers at the source of the construction activity.
- Limit or avoid certain noisy activities during nighttime hours near residential areas.

8.2 Vibration Mitigation

This section provides a summary of vibration impacts from operation or construction, and provides noise mitigation where appropriate and/or required.

8.2.1 Operational Vibration Mitigation

No vibration impacts from train operations are predicted at any sensitive receiver with special (low-vibration) track design, as needed. The prediction model used the building loss and amplification factors from the FTA Guidance Manual. To verify the predicted results, additional site-specific vibration propagation tests would be performed during final design to determine whether there are potential vibration impacts at any of the sensitive receivers along the alignment and if special (low-vibration) track design is needed.

8.2.2 Operations and Maintenance Facility Vibration Mitigation

There would be no vibration related impacts from the OMF operations, and no mitigation is recommended.

8.2.3 Construction Vibration Mitigation

The primary concern from construction vibration in the project corridor is annoyance inside sensitive spaces. The following precautionary vibration mitigation strategies will be considered, as appropriate, to minimize potential construction vibration:

- Pre-construction survey—Prior to beginning construction, a survey of the first row of vibration sensitive buildings adjacent to the alignment would be completed during final design.
- Vibration limits—The Construction Contract Specifications would apply the appropriate FTA construction vibration criteria for building damage to all buildings adjacent to construction activities.
- Vibration monitoring—The contractor would be required to monitor vibration from high-vibration construction activities at the closest representative building where lower vibration limits for building damage are applicable and at representative locations where complaints of annoyance from vibration are received from building occupants.
- Alternative construction procedures—If high-vibration construction activities must be performed close to vibration sensitive structures and there is potential for exceedance of the construction limits, the contractor would be required to use an alternative procedure that produces lower vibration levels.

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Appendix A
Photographs of Noise and Vibration Monitoring Locations

Photo 1: Aerial View

Photo 2: Looking northwest up Commerce St.

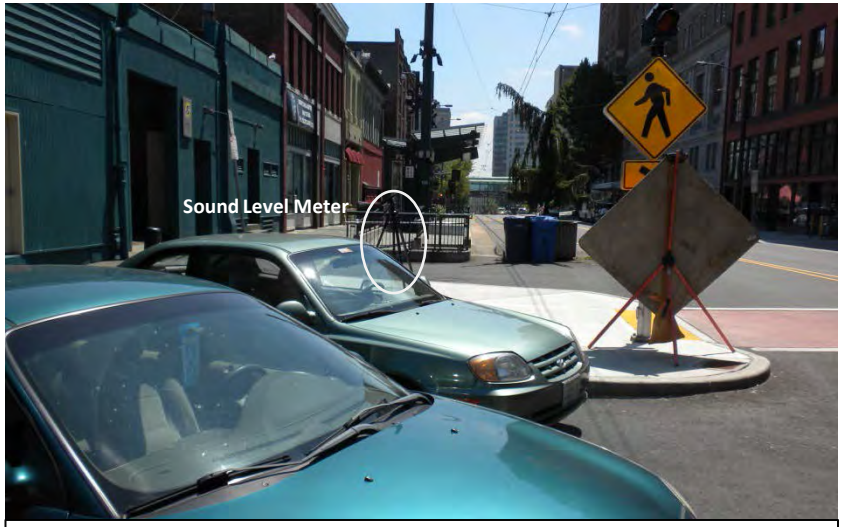

Photo 3: Looking southeast down Commerce St.

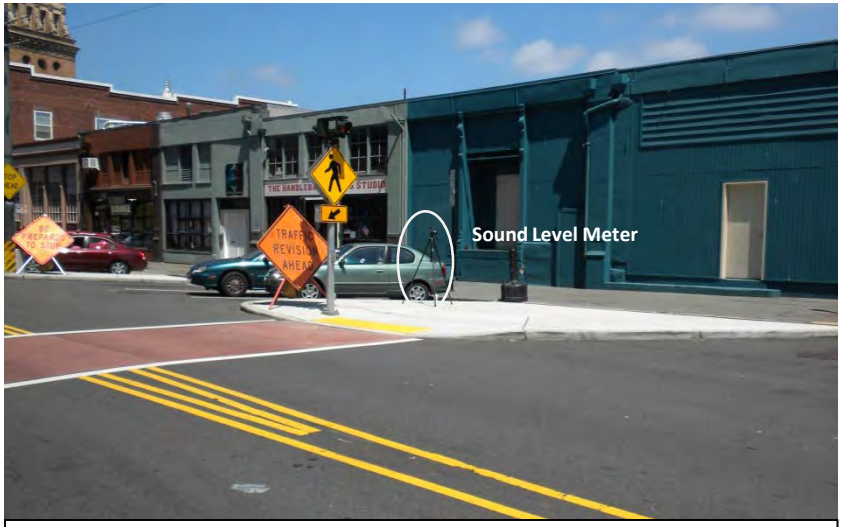

Photo 4: Looking northeast

Monitoring Location M-1
Commerce St., behind 722 Pacific Ave.
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-1
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking southeast

Photo 3: Looking northwest

Photo 4: Looking southwest

Monitoring Location M-2
On S Stadium Way behind 539 Broadway
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-2
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking northwest

Photo 3: Looking southwest at the YWCA

Photo 4: Looking west

Monitoring Location M-3
On the roof of the YWCA along S Stadium Way
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-3
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking south

Photo 3: Looking northwest up N E Street

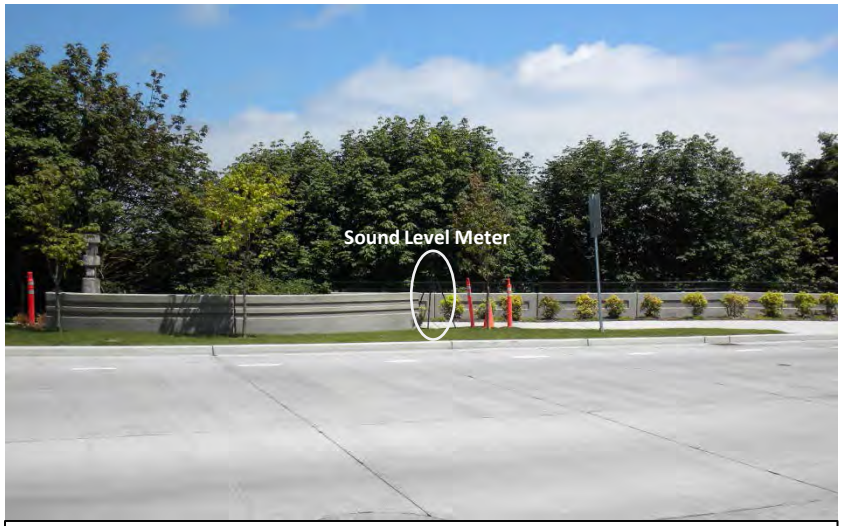

Photo 4: Looking northeast

Monitoring Location M-4
Intersection of N E St. and Division Ave
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-4
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking southwest down N 1st St

Photo 3: Looking southeast toward S Stadium Way

Photo 4: Looking northeast at Stadium High School

Monitoring Location M-5
Stadium School
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-5
Noise Monitoring Locations
Tacoma Link Extension Project

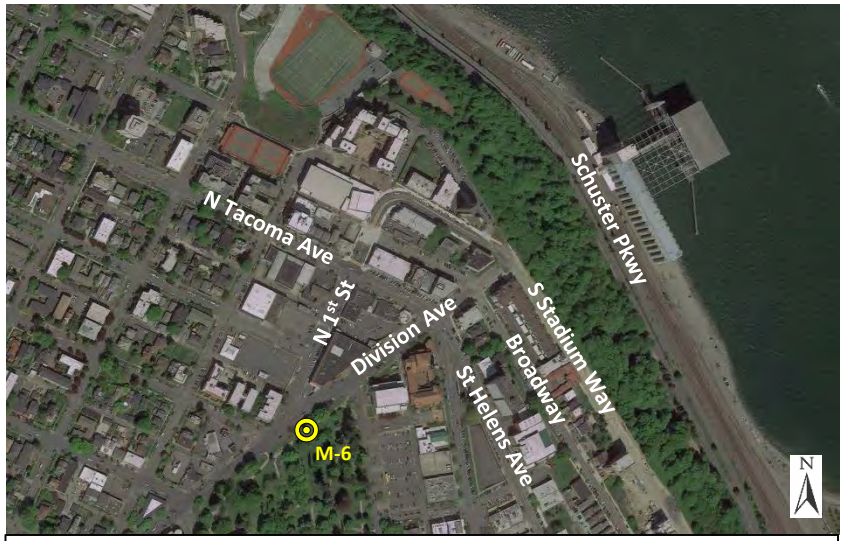

Photo 1: Aerial View

Photo 2: Looking northwest across Division Ave

Photo 3: Looking southwest down Division Ave

Photo 4: Looking northeast

Monitoring Location M-6
N 1st St at Division Ave
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-6
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

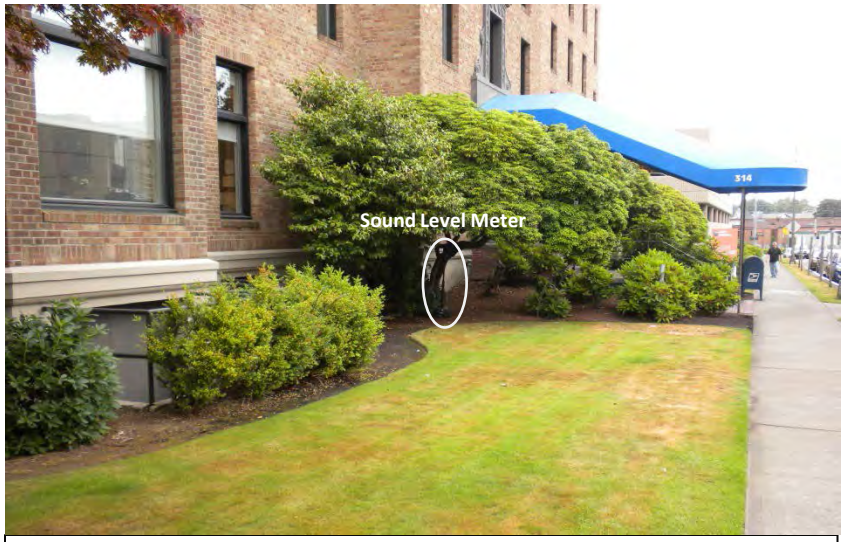

Photo 2: Looking northwest

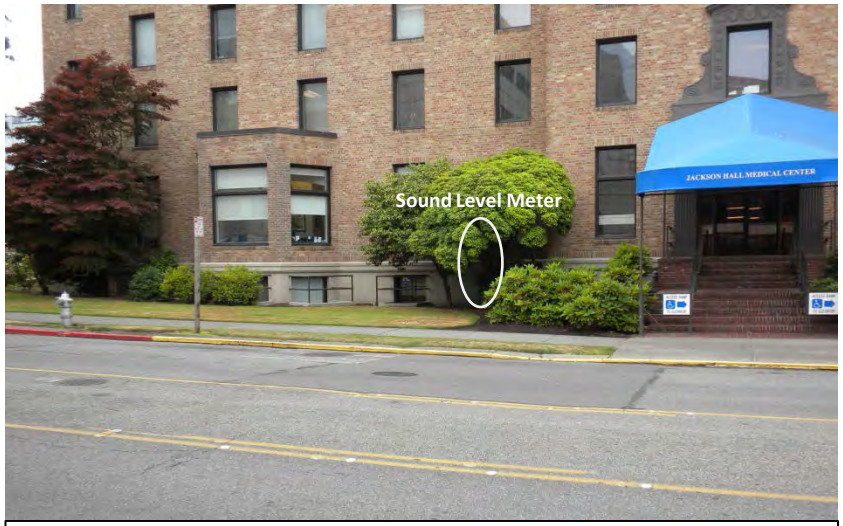

Photo 3: Looking west at Jackson Hall Medical Center

Photo 4: Looking northeast

Monitoring Location M-7
Jackson Hill Medical Center (314 MLK Jr Way)
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-7
Noise Monitoring Locations
Tacoma Link Extension Project

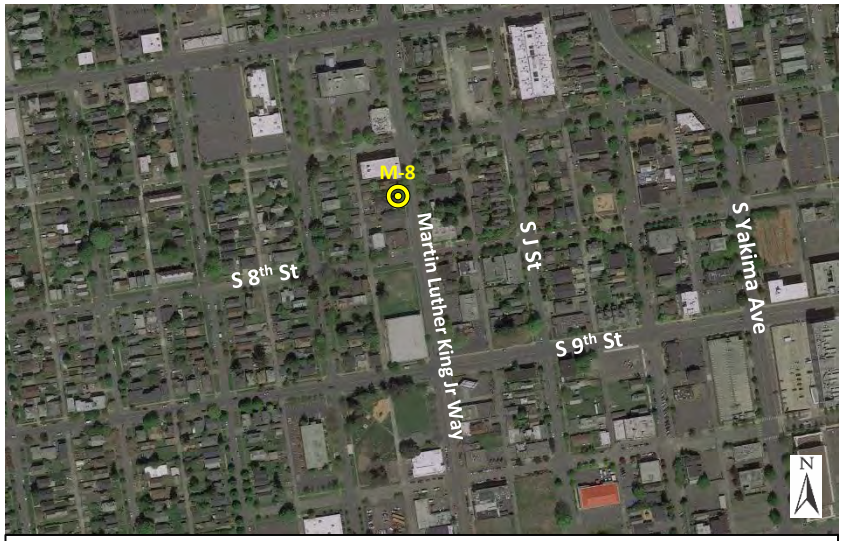

Photo 1: Aerial View

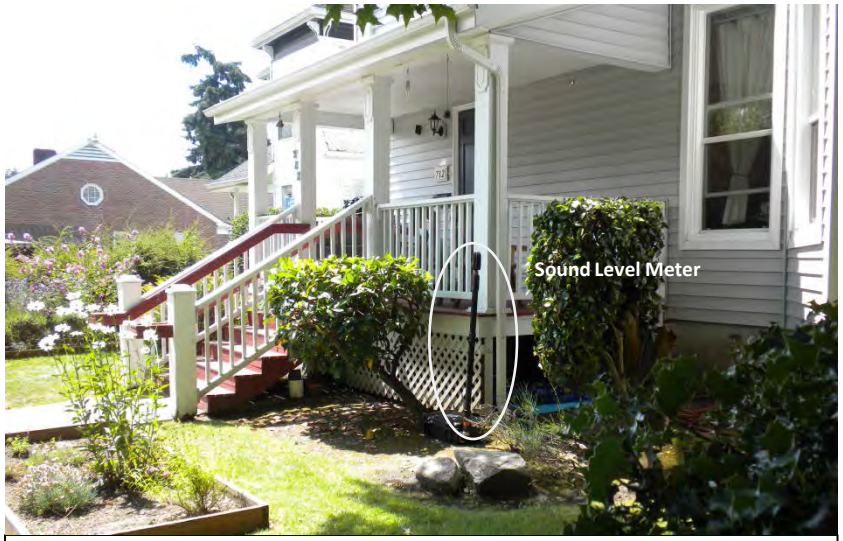

Photo 2: Looking south

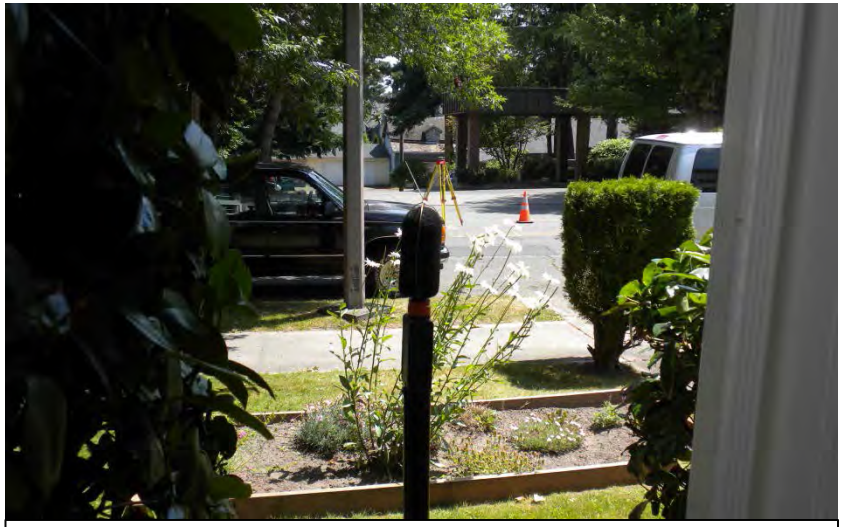

Photo 3: Looking east

Photo 4: Looking northwest

Monitoring Location M-8
712 Martin Luther King Jr Way
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-8
Noise Monitoring Locations
Tacoma Link Extension Project

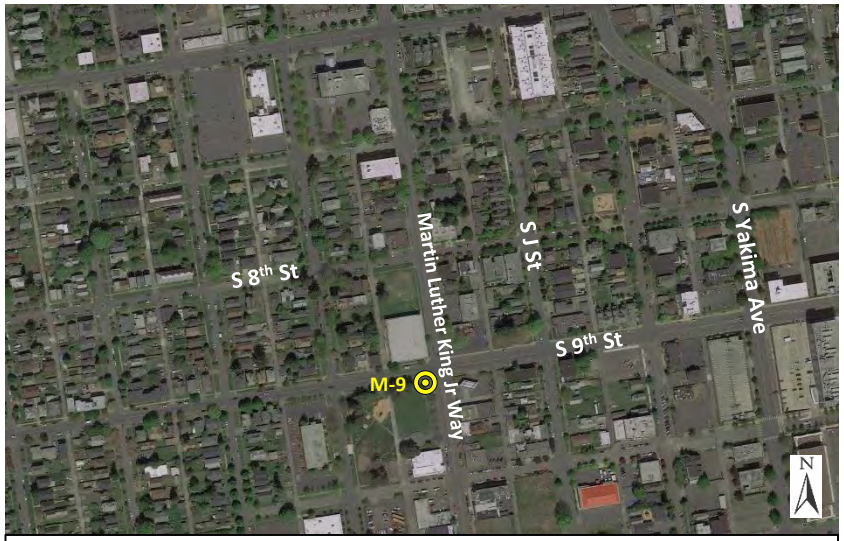

Photo 1: Aerial View

Photo 2: Looking east

Photo 3: Looking south

Photo 4: Looking north

Monitoring Location M-9
Park on the Corner of MLK Jr Way and S 9th St
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-9
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking east

Photo 3: Looking southeast

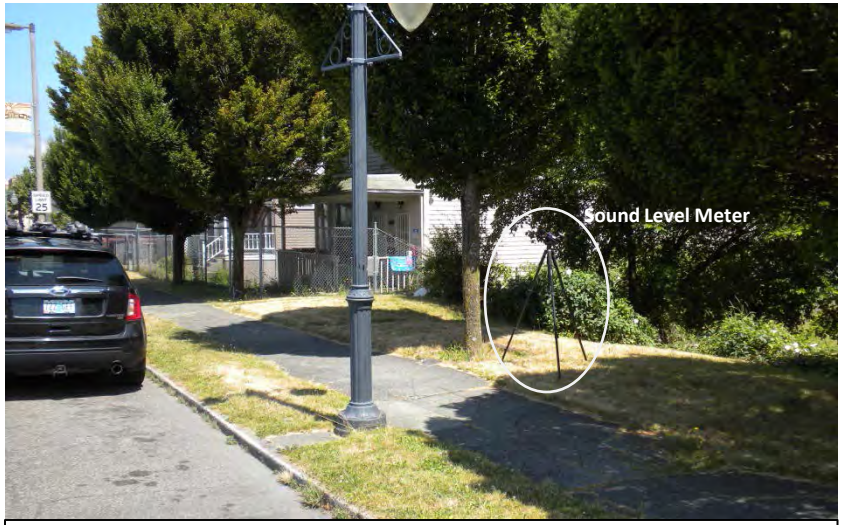

Photo 4: Looking north

Monitoring Location M-10
1423 Martin Luther King Jr Way
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-10
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

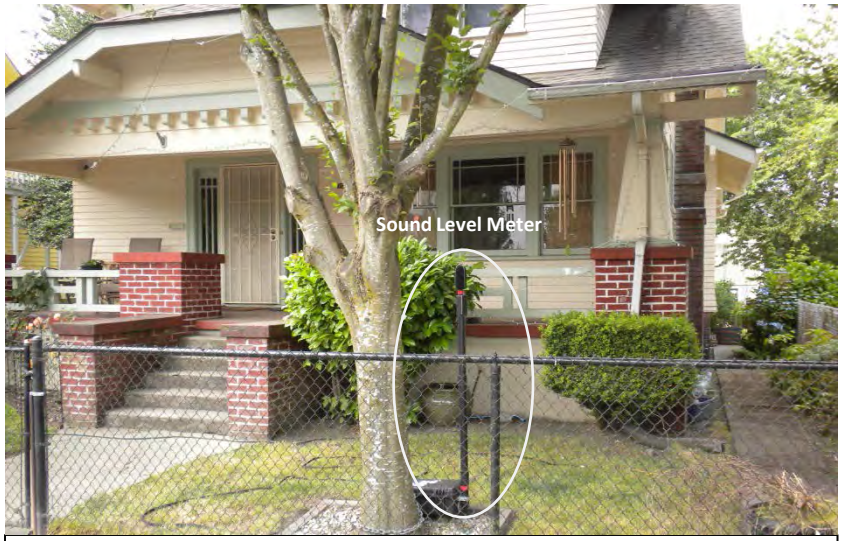

Photo 2: Looking west

Photo 3: Looking northwest up MLK Jr Way

Photo 4: Looking southeast

Monitoring Location M-11
1720 Martin Luther King Jr Way
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-11
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking northeast

Photo 3: Looking northwest

Photo 4: Looking southwest at the Best Western

Monitoring Location M-12
Best Western, 2611 E E St.
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-12
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking west

Photo 3: Looking southeast

Photo 4: Looking north

Monitoring Location M-13
Public Right-of-Way next to 1106 E 26th St.
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-13
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking north

Photo 3: Looking east

Photo 4: Looking southeast

Monitoring Location M-14
1109 E 26th St.
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-14
Noise Monitoring Locations
Tacoma Link Extension Project

Photo 1: Aerial View

Photo 2: Looking west

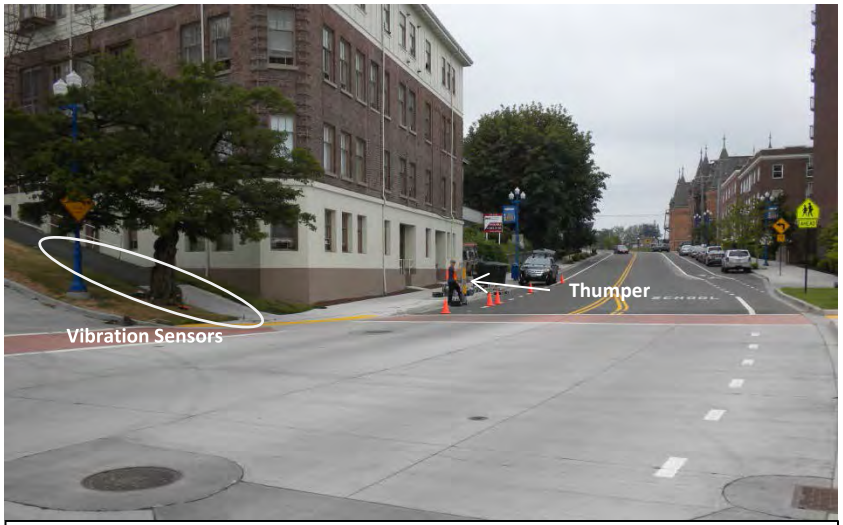

Photo 3: Looking northwest up N E Street

Photo 4: Looking northeast

Vibration Location V-1
Intersection of Division Ave and S Stadium Way
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-15
Vibration Locations
Tacoma Link Extension Project

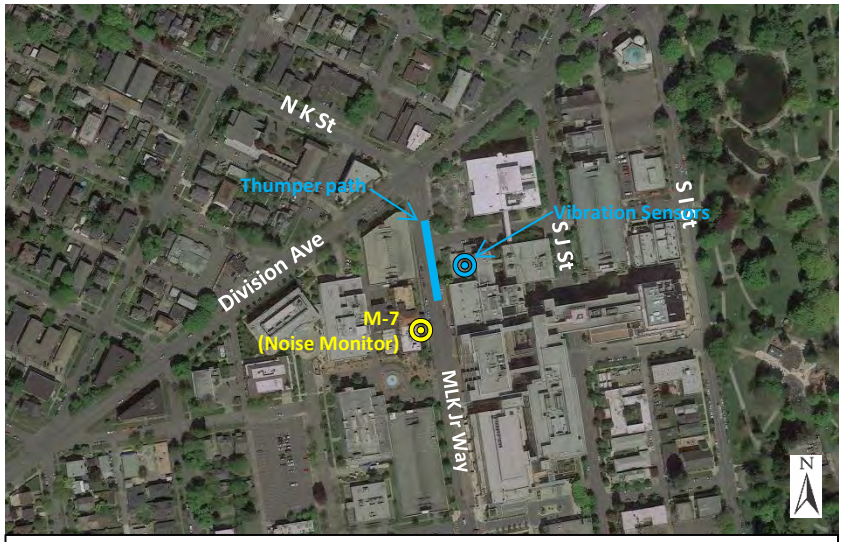

Photo 1: Aerial View

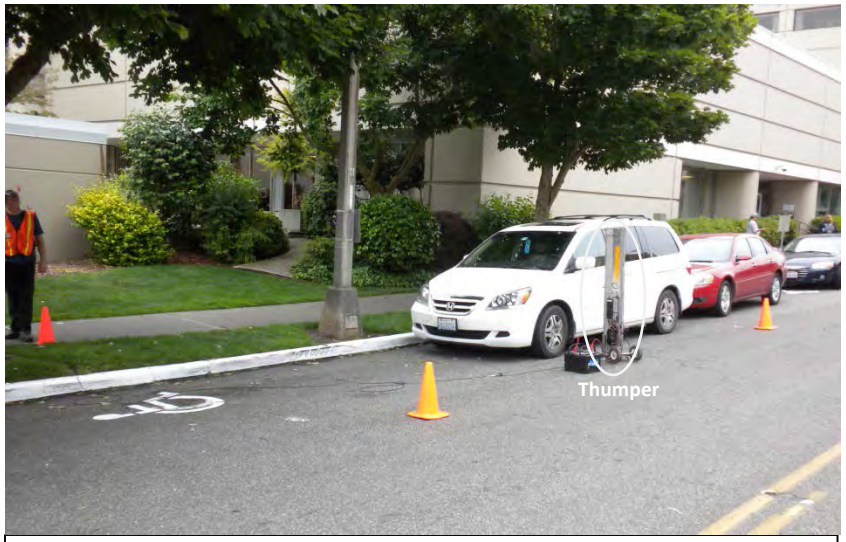

Photo 2: Looking toward the hospital

Photo 3: Hospital courtyard, looking north

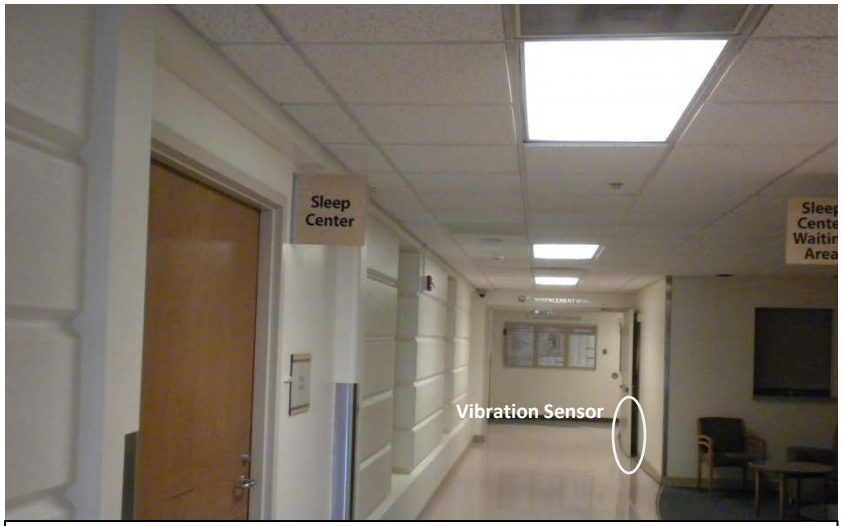

Photo 4: Inside the hospital

Monitoring Location V-2
Tacoma General Hospital
Tacoma, Washington

Michael Minor & Associates
Sound.Vibration.Air
Portland, Oregon

Figure A-16
Noise Monitoring Locations
Tacoma Link Extension Project

Appendix B
Tacoma Link Expansion Light Rail Noise Impact Analysis

Tacoma Link Expansion Light Rail Noise Impact Analysis

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	2007050150	773 Broadway	135	MF Residence on Broadway	MF	25	65	59	Ldn	61	67	--	--	--
	2007050141	760 Commerce St	136	Condo on Commerce St	MF	26	65	59	Ldn	61	67	--	--	--
	2007040012	702 Pacific Ave	140	Rescue Mission On Pacific Ave (1st Floor)	MF	22	67	59	Ldn	63	68	--	--	--
	2007040012	702 Pacific Ave	140	Rescue Mission On Pacific Ave (3rd Floor)	MF	22	67	59	Ldn	63	68	--	--	--
	2372000250	525 Broadway	149	Condos on Broadway (South end, 1st Floor)	MF	9	68	59	Ldn	63	69	--	--	--
	2372000250	525 Broadway	149	Condos on Broadway (South end, 3rd Floor)	MF	9	='Analysis Worksheet'!J30	59	Ldn	63	69	--	--	--
	2372000250	525 Broadway	149	Condos on Broadway (North end, 1st Floor)	MF	9	68	59	Ldn	63	69	--	--	--
	2372000250	525 Broadway	149	Condos on Broadway (North end, 3rd Floor)	MF	9	68	59	Ldn	63	69	--	--	--
	9009130320	505 Broadway	151	Condos on Broadway (1st Floor)	MF	7	68	59	Ldn	63	69	--	--	--
	9009130320	505 Broadway	151	Condos on Broadway (3rd Floor)	MF	7	68	59	Ldn	63	69	--	--	--
	9009130320	505 Broadway	151	Condos on Broadway (5th Floor)	MF	7	68	59	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (South facing rooms, 1st Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (South facing rooms, 3rd Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (South facing rooms, 5th Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (East facing rooms, 1st Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (East facing rooms, 3rd Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (East facing rooms, 5th Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (North facing rooms, 1st Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (North facing rooms, 3rd Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050030	431 Broadway	153	MF Residence on Broadway (North facing rooms, 5th Floor)	MF	4	68	60	Ldn	63	69	--	--	--
	2004050070	405 Broadway	154	YWCA on Broadway (1st Floor)	MF	5	71	60	Ldn	66	71	--	--	--
M-3: 71.1 Ldn	2004050070	405 Broadway	154	YWCA on Broadway (3rd Floor)	MF	8	71	60	Ldn	66	71	--	--	--
	2002050150	251 Broadway	157	MF Residence on Broadway	MF	4	71	57	Ldn	66	71	--	--	--
	2002050150	251 Broadway	157	MF Residence on Broadway	MF	6	71	57	Ldn	66	71	--	--	--

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	9005500010	235 Broadway	158	Condos on Broadway (1st Floor)	MF	10	71	57	Ldn	66	71	--	--	--
	9005500010	235 Broadway	158	Condos on Broadway (3rd Floor)	MF	10	71	57	Ldn	66	71	--	--	--
	9005500010	235 Broadway	158	Condos on Broadway (5th Floor and up)	MF	18	71	57	Ldn	66	71	--	--	--
	9006690020	207 Broadway	162	Condos on Broadway (1st Floor)	MF	2	71	60	Ldn	66	71	--	--	--
	9006690020	207 Broadway	162	Condos on Broadway (3rd Floor)	MF	2	71	60	Ldn	66	71	--	--	--
	9006690020	207 Broadway	162	Condos on Broadway (5th Floor)	MF	2	71	60	Ldn	66	71	--	--	--
	9005460010	201 Broadway	163	Condos on Broadway (1st Floor)	MF	2	71	55	Ldn	66	71	--	--	--
	9005460010	201 Broadway	163	Condos on Broadway (3rd Floor)	MF	1	71	55	Ldn	66	71	--	--	--
	2000050130	55 Broadway	164	MF Residence on Broadway	MF	3	71	54	Ldn	66	71	--	--	--
	2000050120	49 Broadway	165	MF Residence on Broadway	MF	2	71	55	Ldn	66	71	--	--	--
	2000050100	45 Broadway	164	MF Residence on Broadway (1st Floor)	MF	2	71	55	Ldn	66	71	--	--	--
	2000050100	45 Broadway	164	MF Residence on Broadway (3rd Floor)	MF	1	71	55	Ldn	66	71	--	--	--
	2000050090	43 Broadway	166	MF Residence on Broadway (1st Floor)	MF	2	71	56	Ldn	66	71	--	--	--
	2000050090	43 Broadway	166	MF Residence on Broadway (3rd Floor)	MF	2	71	56	Ldn	66	71	--	--	--
	9044700022	35 Broadway	166	Condos on Broadway (1st Floor)	MF	3	71	60	Ldn	66	71	--	--	--
	9044700022	35 Broadway	166	Condos on Broadway (3rd Floor)	MF	3	71	60	Ldn	66	71	--	--	--
	2000050060	31 Broadway	167	MF Residence on Broadway (1st Floor)	MF	4	71	60	Ldn	66	71	--	--	--
	2000050060	31 Broadway	167	MF Residence on Broadway (3rd Floor)	MF	4	71	60	Ldn	66	71	--	--	--
	2000050060	31 Broadway	167	MF Residence on Broadway (5th Floor)	MF	4	71	60	Ldn	66	71	--	--	--
M-4: 65.9 Leq, 64 Ldn	9006010210	1 Broadway	168	Condos on Broadway (South section, 1st Floor)	MF	16	71	60	Ldn	66	71	--	--	--
	9006010210	1 Broadway	168	Condos on Broadway (South section, 3rd Floor)	MF	4	71	60	Ldn	66	71	--	--	--
	9006010210	1 Broadway	168	Condos on Broadway (North section, 1st Floor)	MF	12	71	60	Ldn	66	71	--	--	--
	9006010210	1 Broadway	168	Condos on Broadway (North section, 3rd Floor)	MF	12	71	60	Ldn	66	71	--	--	--
	9006010210	1 Broadway	168	Condos on Broadway (North section, 5th Floor)	MF	6	71	60	Ldn	66	71	--	--	--
	2000070010	1 St Helens Ave	171	MF Residence on St Helens Ave (1st Floor)	MF	5	71	49	Ldn	66	71	--	--	--
	2000070010	1 St Helens Ave	171	MF Residence on St Helens Ave (3rd Floor)	MF	5	71	49	Ldn	66	71	--	--	--
	2000070040	17 St Helens Ave	168	MF Residence on St Helens Ave	MF	24	57	44	Ldn	57	63	--	--	--
	2000120010	20 Tacoma Ave	182	First Presbyterian Church	CH	1	57	43	Leq	62	68	--	--	--
	2000130010	5 S G St	185	Tacoma Bible Presbyterian Church	CH	1	64	44	Leq	66	71	--	--	--
	2030100070	1 N Broadway	172	MF Residence on N Broadway (1st Floor)	MF	16	71	60	Ldn	66	71	--	--	--
	2030100070	1 N Broadway	172	MF Residence on N Broadway (3rd Floor)	MF	15	71	60	Ldn	66	71	--	--	--
	9006260020	25 N Broadway	176	Condos on N Broadway (1st Floor)	MF	5	71	60	Ldn	66	71	--	--	--

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	9006260020	25 N Broadway	176	Condos on N Broadway (3rd Floor)	MF	5	71	60	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (North facing apartments, 1st Floor)	MF	6	71	58	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (North facing apartments, 3rd Floor)	MF	3	71	58	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (East facing apartments, 1st Floor)	MF	8	71	58	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (East facing apartments, 3rd Floor)	MF	4	71	58	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (South facing apartments, 1st Floor)	MF	6	71	58	Ldn	66	71	--	--	--
	2031150020	715 N 1st St	187	MF Residential Building on N 1st St (South facing apartments, 3rd Floor)	MF	3	71	58	Ldn	66	71	--	--	--
	2031150010	123 N Yakima Ave	188	MF Residential Building on N Yakima Ave	MF	29	71	44	Ldn	66	71	--	--	--
M-5: 67.2 Leq	2031100040	111 N E St	178	Stadium High School	SC	1	67	56	Leq	68	73	--	--	--
	2030090010	15 N E St	176	MF Residence on N E St (North building, 1st Floor)	MF	6	68	59	Ldn	63	69	--	--	--
	2030090010	15 N E St	176	MF Residence on N E St (North building, 3rdFloor)	MF	3	68	59	Ldn	63	69	--	--	--
	2030090010	15 N E St	176	MF Residence on N E St (South building, 1st Floor)	MF	6	68	59	Ldn	63	69	--	--	--
	2030090010	15 N E St	176	MF Residence on N E St (South building, 3rdFloor)	MF	3	68	59	Ldn	63	69	--	--	--
	7867000150	1 N Stadium Way	174	Condos on N Stadium Way (1st Floor)	MF	2	68	59	Ldn	63	69	--	--	--
	7867000150	1 N Stadium Way	174	Condos on N Stadium Way (3rd Floor)	MF	2	68	59	Ldn	63	69	--	--	--
	7867000150	1 N Stadium Way	174	Condos on N Stadium Way (5th Floor)	MF	2	68	59	Ldn	63	69	--	--	--
	7867000150	1 N Stadium Way	174	Condos on N Stadium Way (6th Floor and up)	MF	10	68	59	Ldn	63	69	--	--	--
	2032190030	211 N J St	197	SF Residence on N J St	SF	1	59	51	Ldn	58	64	--	--	--
	2032200030	206 N J St	198	Church on N J St	CH	1	61	55	Leq	64	70	--	--	--
	2032200020	212 N J St	199	MF Residence on N J St	MF	8	59	55	Ldn	58	64	--	--	--
	2032210061	1019 Division Ave	200	Medical Office on Division Ave	MD	1	60	53	Leq	63	69	--	--	--
	2032220011	1105 Division Ave	201	Medical Office on Division Ave	MD	1	57	50	Leq	62	68	--	--	--
	2001180010	902 Division Ave	194	Church on Division St	CH	1	63	56	Leq	65	71	--	--	--
	2002190010	209 S J St	196	Church on S J St	CH	1	62	54	Leq	64	70	--	--	--
	2002200041	209 MLK Jr Way	202	Medical Office on MLK Jr Way	MD	1	61	50	Leq	64	70	--	--	--
	2003210010	315 MLK Jr Way	204	Hospital Building on MLK Jr Way	MD	1	62	56	Leq	64	70	--	--	--
	2004210023	423 MLK Jr Way	206	Hospital Building on MLK Jr Way (North Building)	HP	1	62	60	Ldn	59	65	1	--	Impact to exterior face of hospital; no impacts to interior rooms
	2004210023	423 MLK Jr Way	208	Hospital Building on MLK Jr Way (South Building)	MD	1	62	56	Leq	64	70	--	--	--
	2005210042	521 MLK Jr Way	213	Medical Building on MLK Jr Way	MD	1	63	55	Leq	65	71	--	--	--
M-7: 62.2 Ldn	2003220011	314 MLK Jr Way	204	Medical Building on MLK Jr Way (Jackson Hall Medical Center)	MD	1	61	54	Leq	64	70	--	--	--

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	2006210040	601 MLK Jr Way	215	INUA KIJANA / SYLVESTER HOUSE (1st Floor)	MF	2	66	60	Ldn	62	68	--	--	--
	2006210040	601 MLK Jr Way	215	INUA KIJANA / SYLVESTER HOUSE (Second Floor)	MF	2	66	60	Ldn	62	68	--	--	--
	2006210030	1016 6th Ave	215	MF Residence on 6th Ave	MF	4	63	57	Ldn	60	66	--	--	--
	2006210020	1014 6th Ave	215	Duplex on 6th Ave	MF	2	63	55	Ldn	60	66	--	--	--
	2006210010	1012 6th Ave	215	Triplex on 6th Ave	MF	3	63	53	Ldn	60	66	--	--	--
	2006210060	611 MLK Jr Way	216	Triplex on MLK Jr Way	MF	3	63	57	Ldn	60	66	--	--	--
	2006210070	615 MLK Jr Way	216	Duplex on MLK Jr Way	MF	2	63	57	Ldn	60	66	--	--	--
	2006210080	617 MLK Jr Way	216	Duplex on MLK Jr Way	MF	2	63	57	Ldn	60	66	--	--	--
	2006210090	619 MLK Jr Way	217	Quadraplex on MLK Jr Way	MF	4	63	57	Ldn	60	66	--	--	--
	2006210100	621 MLK Jr Way	217	SF Residence on MLK Jr Way	SF	1	63	57	Ldn	60	66	--	--	--
	2006210110	623 MLK Jr Way	217	Duplex on MLK Jr Way	MF	2	63	57	Ldn	60	66	--	--	--
	2007210022	1020 S 7th St	218	Duplex on S 7th St	MF	2	64	60	Ldn	61	66	--	--	--
	2007210013	1016 S 7th St	218	SF Residence on S 7th St	SF	1	64	54	Ldn	61	66	--	--	--
	2007210023	705 MLK Jr Way	219	Triplex on MLK Jr Way	MF	3	64	60	Ldn	61	66	--	--	--
	2007210050	707 MLK Jr Way	219	MF Residence on MLK Jr Way	MF	4	64	60	Ldn	61	66	--	--	--
	2007220160	722 MLK JR Way	221	Medical Office Building (Acupuncture)	MD	1	64	55	Leq	66	71	--	--	--
	2007220150	1109 S 8th St	221	MF Residence on S 8th St (1st Floor)	MF	6	64	53	Ldn	61	66	--	--	--
	2007220150	1109 S 8th St	221	MF Residence on S 8th St (3rd Floor)	MF	6	64	53	Ldn	61	66	--	--	--
	2007220130	716 MLK JR Way	220	Duplex on MLK Jr Way	MF	2	64	57	Ldn	61	66	--	--	--
M-8: 62.7 Ldn	2007220120	712 MLK Jr Way	220	MF Residence (Phoebe House)	MF	16	64	57	Ldn	61	66	--	--	--
	2007220110	708 MLK Jr Way	219	MF Residence on MLK Jr Way	MF	2	64	57	Ldn	61	66	--	--	--
	2007220100	702 MLK Jr Way	218	MF Residence on MLK Jr Way (East facing apartments, 1st Floor)	MF	6	64	60	Ldn	61	66	--	--	--
	2007220100	702 MLK Jr Way	218	MF Residence on MLK Jr Way (East facing apartments, 3rd Floor)	MF	6	64	60	Ldn	61	66	--	--	--
	2007220100	702 MLK Jr Way	218	MF Residence on MLK Jr Way (North facing apartments, 1st Floor)	MF	12	64	60	Ldn	61	66	--	--	--
	2007220100	702 MLK Jr Way	218	MF Residence on MLK Jr Way (North facing apartments, 3rd Floor)	MF	12	64	60	Ldn	61	66	--	--	--
	2006220060	624 MLK Jr Way	217	Medical Office Building on MLK Jr Way	MD	1	64	55	Leq	66	71	--	--	--
	2006220030	1112 MLK Jr Way	215	Medical Office Building on MLK Jr Way	MD	1	64	50	Leq	66	71	--	--	--
	2008210010	801 MLK Jr Way	222	MF Residence on MLK Jr Way (1st Floor)	MF	6	64	60	Ldn	61	66	--	--	--
	2008210010	801 MLK Jr Way	222	MF Residence on MLK Jr Way (3rd Floor)	MF	3	64	60	Ldn	61	66	--	--	--
	2008210020	1016 S 8th Ave	222	MF Residence on S 8th Ave (1st Floor)	MF	6	64	54	Ldn	61	66	--	--	--
	2008210020	1016 S 8th Ave	222	MF Residence on S 8th Ave (3rd Floor)	MF	3	64	54	Ldn	61	66	--	--	--

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	2008210030	805 MLK Jr Way	223	Duplex on MLK Jr Way	MF	2	64	60	Ldn	61	66	--	--	--
	2008200050	820 S J St	224	Duplex on S J St	MF	2	64	49	Ldn	61	66	--	--	--
	2008220050	824 MLK Jr Way	224	Church on MLK Jr Way	CH	1	64	55	Leq	66	71	--	--	--
	2008230126	1111 S 9th St	225	SF Residence on S 9th St	SF	1	64	50	Ldn	61	66	--	--	--
	2008230010	1112 S 8th St	222	Duplex on S 8th St	MF	2	64	50	Ldn	61	66	--	--	--
	2010210010	1016 S 10th St	230	Church on S 10th St	CH	1	64	56	Leq	66	71	--	--	--
	2010220050	1020 MLK Jr Way	232	Mixed Retail w/ Residential Units	MF	4	64	60	Ldn	61	66	--	--	--
	2010220030	1014 MLK Jr Way	231	Mixed Retail w/ Residential Units	MF	2	64	60	Ldn	61	66	--	--	--
	2012210080	1223 MLK Jr Way	239	Church on MLK Jr Way	CH	1	64	56	Leq	66	71	--	--	--
	2012200030	1212 S J St	239	SF Residence on S J St	SF	1	64	48	Ldn	61	66	--	--	--
	2013210010	1301 MLK Jr Way	241	Church on MLK Jr Way	CH	1	64	55	Leq	66	71	--	--	--
	2013210060	1321 MLK Jr Way	243	Church on MLK Jr Way	CH	1	64	57	Leq	66	71	--	--	--
	2013220090	1109 S 14th St	243	SF Residence on S 14th St	SF	1	64	52	Ldn	61	66	--	--	--
	2014210020	1405 MLK Jr Way	245	MF Residence on MLK Jr Way	MF	5	64	60	Ldn	61	66	--	--	--
	2014210030	1409 MLK Jr Way	246	SF Residence on MLK Jr Way	SF	1	64	59	Ldn	61	66	--	--	--
	2014210040	1411 MLK Jr Way	246	SF Residence on MLK Jr Way	SF	1	64	59	Ldn	61	66	--	--	--
	2014210051	1415 MLK Jr Way	247	Duplex on MLK Jr Way	MF	2	64	60	Ldn	61	66	--	--	--
M-10: 63.6 Leq	2014210090	1423 MLK Jr Way	248	Evangelistic Center Church	CH	1	64	56	Leq	66	71	--	--	--
	2015210050	1515 MLK Jr Way	250	Medical Office	MD	1	64	51	Leq	66	71	--	--	--
	2015200080	1524 S J St	251	MF Residence	MF	12	64	50	Ldn	61	66	--	--	--
	2015230080	1115 S 16th St	251	SF Residence on 16th St	SF	1	64	50	Ldn	61	66	--	--	--
	2015230060	1515 S L St	250	SF Residence on S L St	SF	1	64	50	Ldn	61	66	--	--	--
	2016200093	1624 S J St	252	Future site of Franciscan Medical Building and Parking Garage	MD	1	64	55	Leq	66	71	--	--	--
	2017220102	1728 MLK Jr Way	259	SF Residence on MLK Jr Way	SF	1	64	58	Ldn	61	66	--	--	--
	2017220090	1724 MLK Jr Way	259	Duplex on MLK Jr Way	MF	2	64	59	Ldn	61	66	--	--	--
M-11: 64.1 Ldn	2017220080	1720 MLK Jr Way	258	SF Residence on MLK Jr Way	SF	1	64	59	Ldn	61	66	--	--	--
	2017220070	1714 MLK Jr Way	258	SF Residence on MLK Jr Way	SF	1	64	58	Ldn	61	66	--	--	--
	2017220060	1712 MLK Jr Way	257	Quadraplex on MLK Jr Way	MF	4	64	59	Ldn	61	66	--	--	--
	2017220050	1708 MLK Jr Way	257	SF Residence on MLK Jr Way	SF	1	64	58	Ldn	61	66	--	--	--
	2017220030	1108 S 17th St	256	SF Residence on MLK Jr Way	SF	1	64	54	Ldn	61	66	--	--	--
	2017220010	1110 S 17th St	256	SF Residence on MLK Jr Way	SF	1	64	52	Ldn	61	66	--	--	--
	2016220010	1602 MLK Jr Way	255	Metro Parks People's Community Center	PK	1	64	51	Leq	66	71	--	--	--
	2016230021	1113 S 17th St	255	Little Village Daycare Center	SC	1	64	46	Leq	66	71	--	--	--

					Total Units Analyzed			Impact Analysis				Mod Imp	Sev Imp	
					728							1	0	
Receiver/Area Information								Project	Analysis	FTA Criteria				
Area/Mon Site	Parcel	Address	Station	Description	Type	Units	Ldn/Leq	Ldn/Leq	Type	Mod Imp	Sev Imp	Mod Imp	Sev Imp	Impact Notes
	2016230010	1601 S L St	253	Church on S L St	CH	1	64	45	Leq	66	71	--	--	--
	2018210052	1812 S J St	260	Medical Building on S J St	MD	1	64	53	Leq	66	71	--	--	--
	2019210070	1917 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	45	Ldn	61	66	--	--	--
	2019210080	1921 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	44	Ldn	61	66	--	--	--
	2019220060	1918 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	45	Ldn	61	66	--	--	--
	2019220040	1916 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	45	Ldn	61	66	--	--	--
	2019220050	1914 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	45	Ldn	61	66	--	--	--
	2019220030	1912 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	46	Ldn	61	66	--	--	--
	2018220030	1812 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	56	Ldn	61	66	--	--	--
	2018220020	1808 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	56	Ldn	61	66	--	--	--
	2018220010	1802 MLK Jr Way	260	Duplex on MLK Jr Way	MF	2	64	57	Ldn	61	66	--	--	--
	2017220103	1732 MLK Jr Way	260	SF Residence on MLK Jr Way	SF	1	64	56	Ldn	61	66	--	--	--

Land Use Types

Notation	Land Use
CH	Church
HP	Hospital
HT	Hotel
MD	Noise Sensitive Medical - non sleeping
MF	Multi-Family/Condo
PK	Parks, Pools, and other outdoor uses
REC	Recording and concert halls (NOTE: CAT-1)
SC	School
SF	Single Family
U	Undeveloped Lands or Commercial Use

Appendix C
Tacoma Link Expansion Vibration Projections

Tacoma Link Expansion Vibration Projections

					Total Units Analyzed 110			Exterior Impact Analysis					Vibration Analysis Inside Structure			Vibration Levels w/Special Track		
								Total Impacts			68		w/Structure Coupling	28	Structure Coupling	Final Project Vibration Levels		
Receiver Information								Predicted Levels VdB		FTA Criteria	Sites with Impacts	Impact Bldg Type	Max VdB Max 1/3	Sites with VdB>FTA	Notes on Assumptions	Max VdB Max 1/3	Sites with Impacts	Track Notes
Parcel	Address	Station	Sheet	Description	Type	Bldgs	Dist. NTCL	Broad VdB	Max 1/3									
2007050150	773 Broadway	135	1	MF Residence on Broadway	MF	1	25	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2007050141	760 Commerce St	136	1	Condo on Commerce St	MF	1	26	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2007040012	702 Pacific Ave	140	1	Rescue Mission On Pacific Ave (1st Floor)	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2372000250	525 Broadway	149	2	Condos on Broadway (South end, 1st Floor)	MF	1	39	83	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9009130320	505 Broadway	151	2	Condos on Broadway (1st Floor)	MF	1	33	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2004050030	431 Broadway	153	2	MF Residence on Broadway (South facing rooms, 1st Floor)	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2004050070	405 Broadway	154	2	YWCA on Broadway (1st Floor)	MF	1	23	85	76	72	1	3+ Floor cement or brick structure	69		-7 Vdb Structure Coupling	69		
2002050150	251 Broadway	157	3	MF Residence on Broadway	MF	1	31	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9005500010	235 Broadway	158	3	Condos on Broadway (1st Floor)	MF	1	31	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9006690020	207 Broadway	162	3	Condos on Broadway (1st Floor)	MF	1	26	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9005460010	201 Broadway	163	3	Condos on Broadway (1st Floor)	MF	1	81	79	72	72	1	3+ Floor cement or brick structure	65		-7 Vdb Structure Coupling	65		
2000050130	55 Broadway	164	3	MF Residence on Broadway	MF	1	86	78	72	72	1	3+ Floor cement or brick structure	65		-7 Vdb Structure Coupling	65		
2000050120	49 Broadway	165	3	MF Residence on Broadway	MF	1	76	79	72	72	1	3+ Floor cement or brick structure	65		-7 Vdb Structure Coupling	65		
2000050100	45 Broadway	164	3	MF Residence on Broadway (1st Floor)	MF	1	77	79	72	72	1	3+ Floor cement or brick structure	65		-7 Vdb Structure Coupling	65		
2000050090	43 Broadway	166	3	MF Residence on Broadway (1st Floor)	MF	1	67	80	73	72	1	3+ Floor cement or brick structure	66		-7 Vdb Structure Coupling	66		
9044700022	35 Broadway	166	3	Condos on Broadway (1st Floor)	MF	1	25	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2000050060	31 Broadway	167	3	MF Residence on Broadway (1st Floor)	MF	1	29	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9006010210	1 Broadway	168	3	Condos on Broadway (South section, 1st Floor)	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2000070010	1 St Helens Ave	171	4	MF Residence on St Helens Ave (1st Floor)	MF	1	219	72	68	72		No Impact Predicted				68		
2000070040	17 St Helens Ave	168	4	MF Residence on St Helens Ave	MF	1	234	72	68	72		No Impact Predicted				68		
2000120010	20 Tacoma Ave	182	4	First Presbyterian Church	CH	1	326	72	68	75		No Impact Predicted				68		
2000130010	5 S G St	185	4	Tacoma Bible Presbyterian Church	CH	1	270	72	68	75		No Impact Predicted				68		
2030100070	1 N Broadway	172	5	MF Residence on N Broadway (1st Floor)	MF	1	26	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
9006260020	25 N Broadway	176	5	Condos on N Broadway (1st Floor)	MF	1	25	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2031150020	715 N 1st St	187	5	MF Residential Building on N 1st St (North facing apartments, 1st Floor)	MF	1	42	83	74	72	1	3+ Floor cement or brick structure	67		-7 Vdb Structure Coupling	67		

								Total Units Analyzed 110									
								Exterior Impact Analysis					Vibration Analysis Inside Structure			Vibration Levels w/Special Track		
								Total Impacts			68		w/Structure Coupling	28	Structure Coupling	Final Project Vibration Levels		
Receiver Information								Predicted Levels VdB		FTA Criteria	Sites with Impacts	Impact Bldg Type	Max VdB Max 1/3	Sites with VdB>FTA	Notes on Assumptions	Max VdB Max 1/3	Sites with Impacts	Track Notes
Parcel	Address	Station	Sheet	Description	Type	Bldgs	Dist. NTCL	Broad VdB	Max 1/3									
2031150010	123 N Yakima Ave	188	5	MF Residential Building on N Yakima Ave	MF	1	236	72	68	72		No Impact Predicted				68		
2031100040	111 N E St	178	5	Stadium High School	SC	1	27	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2030090010	15 N E St	176	5	MF Residence on N E St (North building, 1st Floor)	MF	1	38	83	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
7867000150	1 N Stadium Way	174	5	Condos on N Stadium Way (1st Floor)	MF	1	38	83	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2032190030	211 N J St	197	6	SF Residence on N J St	SF	1	162	72	68	72		No Impact Predicted				68		
2032200030	206 N J St	198	6	Church on N J St	CH	1	37	83	75	75	1	Large 1-2 floor wood structure	73		-2 Vdb Structure Coupling	73		
2032200020	212 N J St	199	6	MF Residence on N J St	MF	1	72	80	73	72	1	Large 1-2 floor wood structure	71		-2 Vdb Structure Coupling	71		
2032210061	1019 Division Ave	200	6	Medical Office on Division Ave	MD	1	50	82	74	84		No Impact Predicted				74		
2032220011	1105 Division Ave	201	6	Medical Office on Division Ave	MD	1	95	77	71	84		No Impact Predicted				71		
2001180010	902 Division Ave	194	7	Church on Division St	CH	1	25	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2002190010	209 S J St	196	7	Church on S J St	CH	1	42	83	74	75		3+ Floor cement or brick structure				74		
2002200041	209 MLK Jr Way	202	7	Medical Office on MLK Jr Way	MD	1	100	77	71	84		No Impact Predicted				71		
2003210010	315 MLK Jr Way	204	7	Hospital Building on MLK Jr Way	MD	1	20	58	53	84		No Impact Predicted				53		
2004210023	423 MLK Jr Way	206	7	Hospital Building on MLK Jr Way (North Building)	HP	1	20	58	53	65		No Impact Predicted				53		
2004210023	423 MLK Jr Way	208	7	Hospital Building on MLK Jr Way (South Building)	MD	1	20	58	53	84		No Impact Predicted				53		
2005210042	521 MLK Jr Way	213	7	Medical Building on MLK Jr Way	MD	1	30	84	75	84		No Impact Predicted				75		
2003220011	314 MLK Jr Way	204	7	Medical Building on MLK Jr Way (Jackson Hall Medical Center)	MD	1	48	82	74	84		No Impact Predicted				74		
2006210040	601 MLK Jr Way	215	8	INUA KIJANA / SYLVESTER HOUSE (1st Floor)	MF	1	25	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2006210030	1016 6th Ave	215	8	MF Residence on 6th Ave	MF	1	56	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210020	1014 6th Ave	215	8	Duplex on 6th Ave	MF	1	85	78	72	72	1	Large 1-2 floor wood structure	70		-2 Vdb Structure Coupling	70		
2006210010	1012 6th Ave	215	8	Triplex on 6th Ave	MF	1	115	75	70	72		Large 1-2 floor wood structure				70		
2006210060	611 MLK Jr Way	216	8	Triplex on MLK Jr Way	MF	1	58	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210070	615 MLK Jr Way	216	8	Duplex on MLK Jr Way	MF	1	52	82	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210080	617 MLK Jr Way	216	8	Duplex on MLK Jr Way	MF	1	53	82	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210090	619 MLK Jr Way	217	8	Quadraplex on MLK Jr Way	MF	1	56	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210100	621 MLK Jr Way	217	8	SF Residence on MLK Jr Way	SF	1	57	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2006210110	623 MLK Jr Way	217	8	Duplex on MLK Jr Way	MF	1	55	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2007210022	1020 S 7th St	218	8	Duplex on S 7th St	MF	1	30	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2007210013	1016 S 7th St	218	8	SF Residence on S 7th St	SF	1	97	77	71	72		No Impact Predicted				71		
2007210023	705 MLK Jr Way	219	8	Triplex on MLK Jr Way	MF	1	30	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2007210050	707 MLK Jr Way	219	8	MF Residence on MLK Jr Way	MF	1	30	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track

								Total Units Analyzed 110									
								Exterior Impact Analysis					Vibration Analysis Inside Structure			Vibration Levels w/Special Track		
								Total Impacts			68		w/Structure Coupling	28	Structure Coupling	Final Project Vibration Levels		
Receiver Information								Predicted Levels VdB		FTA Criteria	Sites with Impacts	Impact Bldg Type	Max VdB Max 1/3	Sites with VdB>FTA	Notes on Assumptions	Max VdB Max 1/3	Sites with Impacts	Track Notes
Parcel	Address	Station	Sheet	Description	Type	Bldgs	Dist. NTCL	Broad VdB	Max 1/3									
2007220160	722 MLK JR Way	221	8	Medical Office Building (Acupuncture)	MD	1	30	84	75	84		No Impact Predicted				75		
2007220150	1109 S 8th St	221	8	MF Residence on S 8th St (1st Floor)	MF	1	115	75	70	72		No Impact Predicted				70		
2007220130	716 MLK JR Way	220	8	Duplex on MLK Jr Way	MF	1	56	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2007220120	712 MLK Jr Way	220	8	MF Residence (Phoebe House)	MF	1	51	82	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2007220110	708 MLK Jr Way	219	8	MF Residence on MLK Jr Way	MF	1	56	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2007220100	702 MLK Jr Way	218	8	MF Residence on MLK Jr Way (East facing apartments, 1st Floor)	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2006220060	624 MLK Jr Way	217	8	Medical Office Building on MLK Jr Way	MD	1	32	84	75	84		No Impact Predicted				75		
2006220030	1112 MLK Jr Way	215	8	Medical Office Building on MLK Jr Way	MD	1	88	78	72	84		No Impact Predicted				72		
2008210010	801 MLK Jr Way	222	9	MF Residence on MLK Jr Way (1st Floor)	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2008210020	1016 S 8th Ave	222	9	MF Residence on S 8th Ave (1st Floor)	MF	1	88	78	72	72	1	3+ Floor cement or brick structure	65		-7 Vdb Structure Coupling	65		
2008210030	805 MLK Jr Way	223	9	Duplex on MLK Jr Way	MF	1	30	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2008200050	820 S J St	224	9	Duplex on S J St	MF	1	226	72	68	72		No Impact Predicted				68		
2008220050	824 MLK Jr Way	224	9	Church on MLK Jr Way	CH	1	30	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2008230126	1111 S 9th St	225	9	SF Residence on S 9th St	SF	1	188	72	68	72		No Impact Predicted				68		
2008230010	1112 S 8th St	222	9	Duplex on S 8th St	MF	1	186	72	68	72		No Impact Predicted				68		
2010210010	1016 S 10th St	230	10	Church on S 10th St	CH	1	26	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2010220050	1020 MLK Jr Way	232	10	Mixed Retail w/ Residential Units	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2010220030	1014 MLK Jr Way	231	10	Mixed Retail w/ Residential Units	MF	1	30	84	75	72	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2012210080	1223 MLK Jr Way	239	11	Church on MLK Jr Way	CH	1	28	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2012200030	1212 S J St	239	11	SF Residence on S J St	SF	1	255	72	68	72		No Impact Predicted				68		
2013210010	1301 MLK Jr Way	241	11	Church on MLK Jr Way	CH	1	30	84	75	75	1	3+ Floor cement or brick structure	68		-7 Vdb Structure Coupling	68		
2013210060	1321 MLK Jr Way	243	11	Church on MLK Jr Way	CH	1	21	85	76	75	1	3+ Floor cement or brick structure	69		-7 Vdb Structure Coupling	69		
2013220090	1109 S 14th St	243	11	SF Residence on S 14th St	SF	1	132	74	69	72		No Impact Predicted				69		
2014210020	1405 MLK Jr Way	245	12	MF Residence on MLK Jr Way	MF	1	30	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2014210030	1409 MLK Jr Way	246	12	SF Residence on MLK Jr Way	SF	1	37	83	75	72	1	Small structure	75	1	No Structure Coupling	70		Special Track
2014210040	1411 MLK Jr Way	246	12	SF Residence on MLK Jr Way	SF	1	35	83	75	72	1	Small structure	75	1	No Structure Coupling	70		Special Track
2014210051	1415 MLK Jr Way	247	12	Duplex on MLK Jr Way	MF	1	28	84	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2014210090	1423 MLK Jr Way	248	12	Evangelistic Center Church	CH	1	26	84	75	75	1	Large 1-2 floor wood structure	73		-2 Vdb Structure Coupling	73		
2015210050	1515 MLK Jr Way	250	12	Medical Office	MD	1	73	80	73	84		No Impact Predicted				73		
2015200080	1524 S J St	251	12	MF Residence	MF	1	200	72	68	72		No Impact Predicted				68		
2015230080	1115 S 16th St	251	12	SF Residence on 16th St	SF	1	185	72	68	72		No Impact Predicted				68		
2015230060	1515 S L St	250	12	SF Residence on S L St	SF	1	185	72	68	72		No Impact Predicted				68		

								Total Units Analyzed 110					Exterior Impact Analysis				Vibration Analysis Inside Structure			Vibration Levels w/Special Track		
								Total Impacts			68		w/Structure Coupling	28	Structure Coupling	Final Project Vibration Levels		
Receiver Information								Predicted Levels VdB		FTA Criteria	Sites with Impacts	Impact Bldg Type	Max VdB Max 1/3	Sites with VdB>FTA	Notes on Assumptions	Max VdB Max 1/3	Sites with Impacts	Track Notes
Parcel	Address	Station	Sheet	Description	Type	Bldgs	Dist. NTCL	Broad VdB	Max 1/3									
2016200093	1624 S J St	252	13	Future site of Franciscan Medical Building and Parking Garage	MD	1	30	84	75	84		No Impact Predicted				75		
2017220102	1728 MLK Jr Way	259	13	SF Residence on MLK Jr Way	SF	1	46	82	74	72	1	Small structure	74	1	No Structure Coupling	69		Special Track
2017220090	1724 MLK Jr Way	259	13	Duplex on MLK Jr Way	MF	1	37	83	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2017220080	1720 MLK Jr Way	258	13	SF Residence on MLK Jr Way	SF	1	39	83	75	72	1	Small structure	75	1	No Structure Coupling	70		Special Track
2017220070	1714 MLK Jr Way	258	13	SF Residence on MLK Jr Way	SF	1	42	83	74	72	1	Small structure	74	1	No Structure Coupling	69		Special Track
2017220060	1712 MLK Jr Way	257	13	Quadraplex on MLK Jr Way	MF	1	37	83	75	72	1	Large 1-2 floor wood structure	73	1	-2 Vdb Structure Coupling	68		Special Track
2017220050	1708 MLK Jr Way	257	13	SF Residence on MLK Jr Way	SF	1	45	82	74	72	1	Small structure	74	1	No Structure Coupling	69		Special Track
2017220030	1108 S 17th St	256	13	SF Residence on MLK Jr Way	SF	1	94	78	71	72		No Impact Predicted				71		
2017220010	1110 S 17th St	256	13	SF Residence on MLK Jr Way	SF	1	130	74	69	72		No Impact Predicted				69		
2016230021	1113 S 17th St	255	13	Little Village Daycare Center	SC	1	185	72	68	75		No Impact Predicted				68		
2016230010	1601 S L St	253	13	Church on S L St	CH	1	213	72	68	75		No Impact Predicted				68		
2018210052	1812 S J St	260	14	Medical Building on S J St	MD	1	52	82	74	84		No Impact Predicted				74		
2019210070	1917 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	491	72	68	72		No Impact Predicted				68		
2019210080	1921 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	542	72	68	72		No Impact Predicted				68		
2019220060	1918 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	510	72	68	72		No Impact Predicted				68		
2019220040	1916 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	481	72	68	72		No Impact Predicted				68		
2019220050	1914 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	444	72	68	72		No Impact Predicted				68		
2019220030	1912 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	418	72	68	72		No Impact Predicted				68		
2018220030	1812 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	67	80	73	72	1	Small structure	73	1	No Structure Coupling	68		Special Track
2018220020	1808 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	62	81	73	72	1	Small structure	73	1	No Structure Coupling	68		Special Track
2018220010	1802 MLK Jr Way	260	14	Duplex on MLK Jr Way	MF	1	56	81	74	72	1	Large 1-2 floor wood structure	72	1	-2 Vdb Structure Coupling	67		Special Track
2017220103	1732 MLK Jr Way	260	14	SF Residence on MLK Jr Way	SF	1	61	81	73	72	1	Small structure	73	1	No Structure Coupling	68		Special Track

Land Use Types

Notation	Land Use
CH	Church
HP	Hospital
HT	Hotel
MD	Noise Sensitive Medical - non sleeping
M	Multi-Family/Condo
PK	Parks, Pools, and other outdoor uses
REC	Recording and concert halls (NOTE: CAT-1)
SC	School
SF	Single Family
U	Undeveloped Lands or Commercial Use